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USAAVLABS TECHNICAL REPORT 67-31

DESIGN FEASIBILITY AND EVALUATION OF A VERTICAL/MODULAR AERIAL DELIVERY SYSTEM (U)

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August 1967

U. S. ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS, VIRGINIA

CONTRACT DA 44-177-AMC-368(T)
DOUGLAS AIRCRAFT COMPANY, INC.
AIRCRAFT DIVISION
LONG BEACH, CALIFORNIA

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(U) This study derives from an indicated potential for major improvements in aerial delivery effectiveness. The basic principles involved are the modifications to V/STOL type aircraft which permit the selective vertical delivery of cargo modules with the aircraft in hover or near-hover mode without compromising the aircraft for other types of missions.

(U) The structures, weight, and control analyses performed by the contractor adequately establish the design feasibility of the concept as it relates to the aircraft. The preliminary design calculations and drawings covering the drop system hardware are well conceived and executed. The contractor's mission analysis and cost effectiveness techniques are responsive and, when evaluated against qualitative considerations, provide a basis for sound decisions.

(U) This command concurs in the approach used by the contractor, the analytical techniques employed, and the conclusions reached. However, because of the mix of missions (deployment, supply, resupply, etc.) normally performed by organic Army aircraft over relatively short distances, the overall effectiveness of the proposed system and its improvement factors over current systems are small. Therefore, this command does not recommend any further consideration of this concept for Army aircraft at this time.

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DESIGN FEASIBILITY AND EVALUATION OF A VERTICAL/MODULAR AERIAL DELIVERY SYSTEM (U)

Final Report
Douglas Report DACLB 33480

By

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(U) ABSTRACT

A concept for aerial delivery of supplies by dropping modules vertically through bottom doors in an aircraft was investigated. Preliminary analysis was conducted to determine the effect on the aircraft structural weight, strength, and aerodynamic performance. A preliminary design of the mechanical cargo handling system was completed. The dynamic effect of dropping cargo on the stability and control characteristics of the aircraft was investigated.

The system was evaluated in comparison to a conventional aerial delivery system for typical missions performed by a forward area transport. The concept was shown to be advantageous for performing resupply missions when operating in the vertical flight mode. It is concluded that the concept has potential application to V/STOL or rotary-wing aircraft.

(U) FOREWORD

This study was conducted by the Aircraft Division of the Douglas Aircraft Company, Inc., Long Beach, California, under Contract DA 44-177-AMC-368(T). Initiated in January 1966, the study was concluded in November 1966.

Jules A. Vichness represented the contracting agency, the U. S. Army Aviation Materiel Laboratories of Fort Eustis, Virginia.

Robert A. Warren, of the Douglas Aircraft Company, was Study Manager. Reginald R. Belding assisted Mr. Warren in the direction of the study. James W. Wollaston was responsible for the Systems Analysis segments of the study.

Randall A. Grueber was responsible for the cargo handling system design, Robert E. Adkisson for the structural analysis, Thomas N. Kyle for the systems costing, Ronald G. Custer for the aerodynamic performance data, and Francis D. Merritt for the stability and control analysis.

The Douglas Aircraft Company wishes to express its appreciation for the assistance of the following individuals and agencies:

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All interpretations and extrapolations of the information provided by the above are the sole responsibility of the authors of this report.

The classification of this report is confidential (not releasable to foreign nationals).

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(U) SYMBOLS

c. g.	center-of-gravity location, percent of mean aerodynamic chord
D	drag, lb
g	acceleration due to gravity, 32.2 ft/sec^2
h	altitude, ft
i_T, i_w	incidence of thrust line and wing chord plane, respectively, to fuselage reference line, positive above fuselage reference line
I_y	pitching-moment of inertia, slug-ft^2
L	lift, lb
m	mass, slugs
M	pitching-moment, ft-lb
n	load factor, $\frac{L}{W}$ or $\frac{-Z}{W}$
q	pitch rate, rad/sec or dynamic pressure, lb/ft^2
s	Laplace operator, d/dt
S	reference area, ft^2
t	time, sec
t_w	mean aerodynamic chord, ft
T	thrust, lb
u, w	disturbance velocity in the X and Z direction, respectively, ft/sec
W	weight, lb
x, y, z	stability axes, positive forward, out right wing and down, respectively
X, Y, Z	forces along the x, y, z axes, lb
Z_T	perpendicular distance from center of gravity to thrust line (positive for thrust line below c.g.)
C_D	drag coefficient, D/qS

C_{D_α}, C_{D_D}, C_{D_q}, C_{D_u}	drag coefficient derivatives with respect to angle of attack, angle of attack rate ($\dot{\alpha}t_w/2V$), pitch rate ($qt_w/2V$), and longitudinal velocity, respectively, per radian
C_L	lift coefficient, L/qS
C_{L_α}, $C_{L_{D_\alpha}}$, C_{L_q}	lift coefficient derivatives with respect to angle of attack, angle of attack rate ($\dot{\alpha}t_w/2V$), and pitch rate ($qt_w/2V$), respectively, per radian
C_m	pitching-moment coefficient, M/qS
C_{m_α}, $C_{m_{D_\alpha}}$, C_{m_q}, C_{m_θ}	pitching-moment coefficient derivative with respect to angle of attack, angle of attack rate ($\dot{\alpha}t_w/2V$), pitch rate ($qt_w/2V$), and pitch angle, respectively, per radian
M_u, M_w, $M_{\dot{w}}$, M_q, M_θ	pitching-moment derivative with respect to longitudinal velocity (1/ft/sec), vertical velocity (1/ft/sec), vertical acceleration ($1/\text{ft/sec}^2$), pitch rate (1/rad/sec), and pitch angle (1/rad), respectively
X_u, X_w	longitudinal-force derivative with respect to longitudinal and vertical velocity, respectively, lb-sec/ft
Z_w, Z_q	normal-force derivatives with respect to vertical velocity (lb-sec/ft) and pitch rate (lb-sec/radian), respectively
α	angle of attack, degrees or radians
γ	flight path angle, degrees or radians
δ_e	control deflection, radians
δ_{se}	control stick deflection, radians
Δ	change
θ	pitch angle, degrees or radians
ξ_T	thrust axis angle of attack = $\alpha + i_T$, degrees
V	distance in feet that module has traveled vertically at time t
H	distance in inches that module has moved horizontally at time t

β	angular rotation of module at time t
V_e	velocity of free airstream
OWE	operating weight empty of the aircraft
C.G.[1]	center of gravity of the aircraft empty
L_n	weight or load in the nth compartment
X_n	distance from the nose to the nth compartment

SUBSCRIPTS

e	elevator deflection (positive, trailing edge down)
F	flap
w	wing
o	zero time
T	thrust

SUPERSCRIPTS

$\cdot$	denotes first derivative with respect to time, i.e., $d\theta/dt$
$\cdot\cdot$	denotes second derivative with respect to time, i.e., $d^2\theta/dt^2$

(U) INTRODUCTION

This study compares two forward-area aerial delivery system concepts from design and cost/effectiveness viewpoints. The purpose of the study is to examine the feasibility of discharging cargo vertically downward through bomb-bay doors in the belly of the aircraft as opposed to current practice where cargo is discharged through aft fuselage doors.

A modified XC-142A was selected as the evaluation vehicle so that both STOL and VTOL operations could be considered over a wide spectrum of radii. The basic aircraft was in tri-service evaluation at the time of this study, adding realism to the performance data. Performance data is based on the June 1966 flight manual.

The base-case delivery system concept, hereafter called the conventional delivery system, is an XC-142A with integrated roller-conveyors to reduce floor friction and buffer boards to guide the cargo and prevent damage to the aircraft. This delivery system discharges cargo through aft doors in airdrop and airland delivery modes, as illustrated at the top of Figure 1.

The advanced delivery system, hereafter called the vertical/modular delivery system, is a modified XC-142A which discharges cargo either vertically downward through bomb-bay doors or through aft doors like the conventional delivery system. The vertical/modular delivery system, illustrated at the bottom of Figure 1, is compared to the conventional delivery system from design, performance, cost and effectiveness points of view in the study.

MAJOR CONSIDERATIONS

This study begins with an assumed need for an aerial delivery system, and seeks to determine whether the conventional or the vertical/modular aerial delivery concept best meets this need. While surface transportation is not considered in this study, the criteria for evaluating the effectiveness of competitive aerial delivery systems are more meaningful in the context of overall forward-area transportation system requirements and alternatives. Before pointing out the major parameters differentiating the conventional and vertical/modular delivery systems, it is desirable to discuss the need for and desirable characteristics of forward-area aerial transport operation from an Army point of view.

The purpose of any forward-area transportation system is either to move or to supply Army units. It follows that the transportation system should be designed to maximize the effectiveness of the units supported. Resupply operations will be emphasized in this study, since cargo handling equipment in an aircraft does not aid in deploying men or vehicles. The weight penalty of the cargo handling equipment is unimportant if the aircraft is volume limited, as is often the case when carrying men or vehicles in many current aircraft.

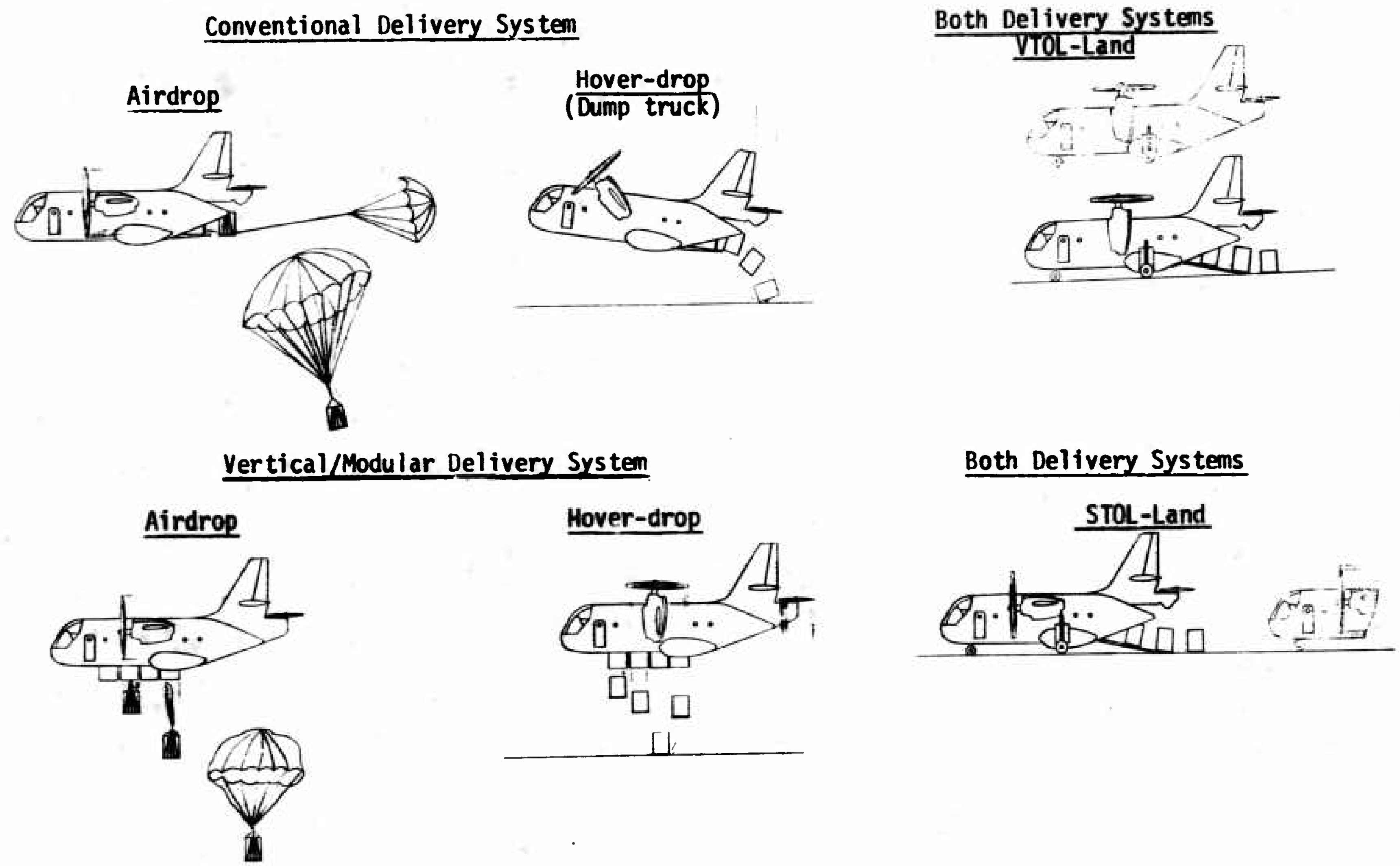

Figure 1. (U) Illustration of Competitive Delivery Modes for Conventional and Vertical/Modular Delivery Systems.

The question of the need for an air line of communications (ALOC) is basically a tradeoff between:

1. system effectiveness
2. system economics

Given that an inland military unit must be moved from one location to another, or that it must be supplied at a given location, the question becomes one of determining the alternative means of meeting the requirement in light of the theater environment. There is no question that surface (truck, pipe, and rail) transportation is more economical than air if there are no impediments to surface movement. The magnitude of the impediments determines the feasibility of surface transportation and, conversely, the need for air transportation. Except for weather and vulnerability considerations, air transportation is feasible with today's VTOL technology, whereas surface transportation becomes less feasible as the impediments increase in magnitude. At some point, surface transportation is infeasible; that is, it cannot provide the minimum transportation system effectiveness required. In essence, both the need for air transportation and the desired characteristics of air transportation must be based on the conditions under which surface transportation is becoming ineffective and inefficient.

Theater environment parameters determining the feasibility of surface or air movement may be classed as parameters existing in the absence of military operations, or as parameters resulting from military operations. Parameters existing in the absence of military operations include:

1. weather and climate (temperature/altitude/humidity/rainfall)
2. terrain
3. vegetation
4. existing transportation facilities

Parameters resulting from military operations in the theater include:

1. number, type, and organic transportation capabilities of military units supported
2. level of activity (transportation route saturation)
3. size and capabilities of enemy force
4. distances involved
5. transportation system capabilities
6. rate of movement

The system effectiveness associated with a given set of the above parameters depends on the judgment of the decision maker due to the importance of the qualitative factors involved. System effectiveness does not lend itself totally to quantitative measurement.

Several interrelated quantitative factors and qualitative considerations, in conjunction with the above parameters, determine overall system effectiveness. These include:

1. tactical mobility
2. stockage levels
3. flexibility
4. command and control
5. response time
6. material consumption (types and quantity of resupply cargo)
7. deployment frequency by unit (men, equipment and supplies moved)
8. security (vulnerability of transportation system to enemy action)
9. transshipment, storage, and redistribution
10. packaging requirements

There is a range of system effectiveness which is acceptable. Achieving each level of effectiveness is dependent on the natural and induced parameters and on their impact on surface and air transportation. System economics determines the optimum alternative transportation system for achieving a given level of system effectiveness, as well as the level of effectiveness realistically attainable. As surface transportation becomes less feasible, air transportation becomes both more effective and less costly in relation to surface transportation.

For a thorough discussion of forward-area aerial resupply, A System Analysis: Air Line of Communication (U), published by DCSLOG, Department of the Army (ref 1), is highly recommended. The relationships between the above parameters are examined in considerable detail in this report.

DELIVERY SYSTEM DIFFERENCES

The major differences between the vertical/modular delivery system and the conventional delivery system are:

1. Payload degradation — the loss of payload capability due to:

   a. System weight — if the aircraft is not volume-limited.

   b. Terrain — terrain slope and vegetation may dictate the delivery modes utilized.

   c. Airfield availability — since an airfield permits higher aircraft gross weights.

   d. Stops per cycle — fuel is consumed at each stop, and refueling would not ordinarily be available where multiple stops are made.

   e. Rigging, parachutes, and cushioning — these reduce usable payload.

f. Thrust-to-weight ratio — the vertical/modular delive-y system can jettison cargo during a vertical landing if an engine is lost.

g. Stability and control — which may restrict the payload that can be carried in certain delivery modes.

2. Cargo handling time — which affects:

a. Cycle time — and thereby delivery system productivity.

b. Exposure time — and thereby the number of aircraft lost to enemy fire, a major cost element.

3. Lost cargo — which reduces system productivity and increases cost, and is the cumulative cargo lost due to:

a. Accuracy — of each delivery system in each delivery mode, a major factor in airdrop deliveries.

b. Damage (impact and handling) — the amount depending on both the delivery system and the delivery mode.

c. Lost aircraft — a negligible cargo loss, even for very high attrition rates.

4. Total system cost — in addition to those listed above, a function of the factors categorized as follows:

a. Research, development, test and evaluation costs

b. Investment cost — for the number of aircraft required based on meeting representative maximum mission.

c. Fixed operating costs — based on pay and allowances of the manpower required, including:

- crew
- maintenance personnel
- support personnel

d. Variable operating costs — primarily a function of utilization and cycles including the costs of:

- fuel
- maintenance materials
- parachutes, rigging, special plywood or pallet bases, and cushioning consumed
- lost cargo
- lost aircraft

5. Qualitative factors — some of which are semi-quantitative, some absolute qualitative differences, and others implied qualitative differences.

   a. Selectivity — the order in which palletized cargo and fuel drums can be discharged from the aircraft.

   b. Stockage/response time/mobility — as the resupply system becomes more responsive and reliable, less reserve supplies must be stocked in the combat area, and the mobility of combat elements is enhanced.

   c. Transshipment/storage/redistribution — if cargo does not have to be transshipped (e.g., from C-130 to UH-1D), supplies need not be handled or stored at the intermediate point. The more direct the shipments from depot to user, the fewer resources that must be committed to redistribution operations.

   d. Operational flexibility — the overall performance of the two delivery systems in carrying both deployment and resupply cargo using several delivery modes.

   e. Command and control — essentially a two-part problem of insuring that the desired cargo is dispatched to the appropriate delivery site, and that the pilot locates the delivery site.

The operational concepts of the two delivery systems being compared and the associated design requirements are discussed in the first two chapters. The results of the design phase of the study are then presented, including mechanical design, structural considerations, and aerodynamic stability and control. The aerodynamic performance and the operational capabilities of the two delivery systems are compared, followed by the presentation of the evaluation mission selected, evaluation methodology, study results, conclusions, and recommendations.

(C) OPERATIONAL CONCEPT (U)

(C) BASIC CONDITIONS (U)

(U) The operational concept for forward-area air transportation is based on those conditions under which surface transportation is inadequate. This means (1) that few surface lines of communication are available or that terrain or vegetation makes road construction difficult, (2) that the enemy can effectively interdict the available roads, (3) that long distances must be covered, or (4) a combination of these conditions.

(C) The operational concept assumes that the aircraft are operating in an area where the enemy has no effective antiaircraft defenses. This condition can be interpreted to mean several things, the most obvious of these being that the enemy does not have a sufficient number of effective antiaircraft weapons. Other interpretations are that friendly forces are not deployed in areas where the enemy has an effective antiaircraft capability unless surface lines of communication are available, or that enemy air defenses are neutralized before Army units are deployed to locations where air transportation would be required to resupply, redeploy, or withdraw these forces.

(U) DELIVERY MODES

Given a combination of cargo, delivery system capabilities, and landing area terrain, there are several delivery modes which might be employed. Each delivery mode, or method of delivery, is specified by the speed and altitude of the aircraft at the instant the cargo is discharged, the means by which cargo is discharged from the aircraft, and the means by which the cargo reaches the ground.

Because of the sensitivity of the differences between the conventional and vertical/modular delivery systems to the delivery modes employed, four delivery modes are considered in this study.

1. STOL-land: The aircraft lands with a ground run and discharges cargo through the aft doors.

2. VTOL-land: The aircraft lands vertically and discharges cargo through the aft doors.

3. Airdrop: The aircraft discharges the cargo at an altitude between 500 and 1,500 feet. The descent of the cargo is retarded by means of a parachute. With the conventional delivery system, cargo is discharged through the aft fuselage, involving extraction by gravity or by parachute. Generally, cargo is ejected vertically downward from the belly of the aircraft with the vertical/modular delivery system. Very large items may be discharged through the aft fuselage as with the conventional delivery system.

4. Hover-drop: Cargo is discharged while the aircraft is hovering at a very low altitude (below 15 feet) and at near-zero forward velocity. Cargo falls to the ground without retarding devices. With the conventional delivery system, cargo rolls out over the rear ramp. Cargo is dropped vertically downward from the belly of the aircraft with the vertical/modular delivery system.

Delivery modes not considered in this study are:

1. Low-level extraction (LO LEX or LAPES).

2. Ground proximity extraction system (GPES).

3. Parachute low-altitude delivery system (PLADS).

4. In-flight ground proximity gravity drop.

These delivery modes may offer greater delivery accuracy in some cases and decrease aircraft exposure time to enemy fire; however, system complexity is increased as well as the percent of cargo damaged. A major reason for not considering these modes in the evaluation is that any area large and smooth enough to employ these types of delivery systems is also suitable for landing the XC-142A. Since cargo is dropped at low altitude in these delivery modes, the aircraft does not enjoy the decreased vulnerability of drops made at higher altitudes.

(C) MILITARY UNIT, UNIT LOCATIONS, AND COMBAT INTENSITY (U)

(U) Before discussing the role of the two competitive delivery systems in deployment and resupply operations, an examination of the sensitivity of the evaluation to three parameters is in order. These parameters are:

1. Military organizational unit(s) supported.

2. Unit locations in relation to each other and in relation to the logistic support base.

3. Combat intensity.

(U) The division is the organizational unit in direct contact with the enemy. Its needs and capabilities are the most important determinates of forward-area transportation system requirements. There are five types of divisions in the U. S. Army at the present time, the structure of which has changed and probably will continue to change over the years. These are the infantry, mechanized, armored, airborne, and airmobile divisions. They differ basically in their firepower, surface mobility, and aerial mobility to match the terrain and types of conflict in which they would be employed. As far as this study is concerned, the division supported determines primarily:

1. The cargo transported by the XC-142A, based on the division's men and equipment, materiel consumption, storage and

redistribution capabilities, and organic surface and aerial transportation capabilities.

2. The expected rate of movement of the division, especially of combat elements of the division.

(C) The airmobile division (TOE 67T) was selected for this study as representative of the type of Army division which would operate in an underdeveloped area against enemy forces that do not possess sophisticated weapons and equipment.

(C) The unit locations in relation to each other and in relation to the logistic support base can be described by specifying:

1. The number and nature of committed division elements.

2. The distances between the logistic support base, the division base, brigade bases, and battalion areas.

(U) The unit locations assumed for the study follow the general deployment pattern shown in Figure 2.

(U) The distances assumed between these geographic areas are given in Table I.

(C) The above distances are quoted from Reference 1, which comments that:

> (C) Existing (December 1964) studies reflect a wide variance of mileages, ranging up to 250 miles for Leg 1 (Logistic Support Base to Division Base) in one instance. Range of 100 to 150 miles between the logistic base and the division base is contained in current Department of the Army and USA Combat Developments Command publications, reflecting approved DA concepts (Reference 1, page 99).

(U) Figure 3 illustrates the combat areas and distances to proportionate linear scales, based on information in Reference 1 (pages 29, 71, 78, 79, and 187).

(C) Throughout the following sections of this report, a clear understanding of the difference between battalion organizational units and the battalion area is required. The battalion area is the forwardmost geographic area within which contact between division units and enemy forces is most likely to occur. One or more complete battalion organizational units of the division are generally operating in the battalion area, as well as parts of several other battalion organizational units. For example, one battalion area defined for calculation purposes in this study contains an infantry battalion, a howitzer battery and a combat engineering platoon, the latter two being subelements of artillery and engineering battalion organizational units. Whole battalions and parts of several battalions likewise may be located at the brigade and division bases.

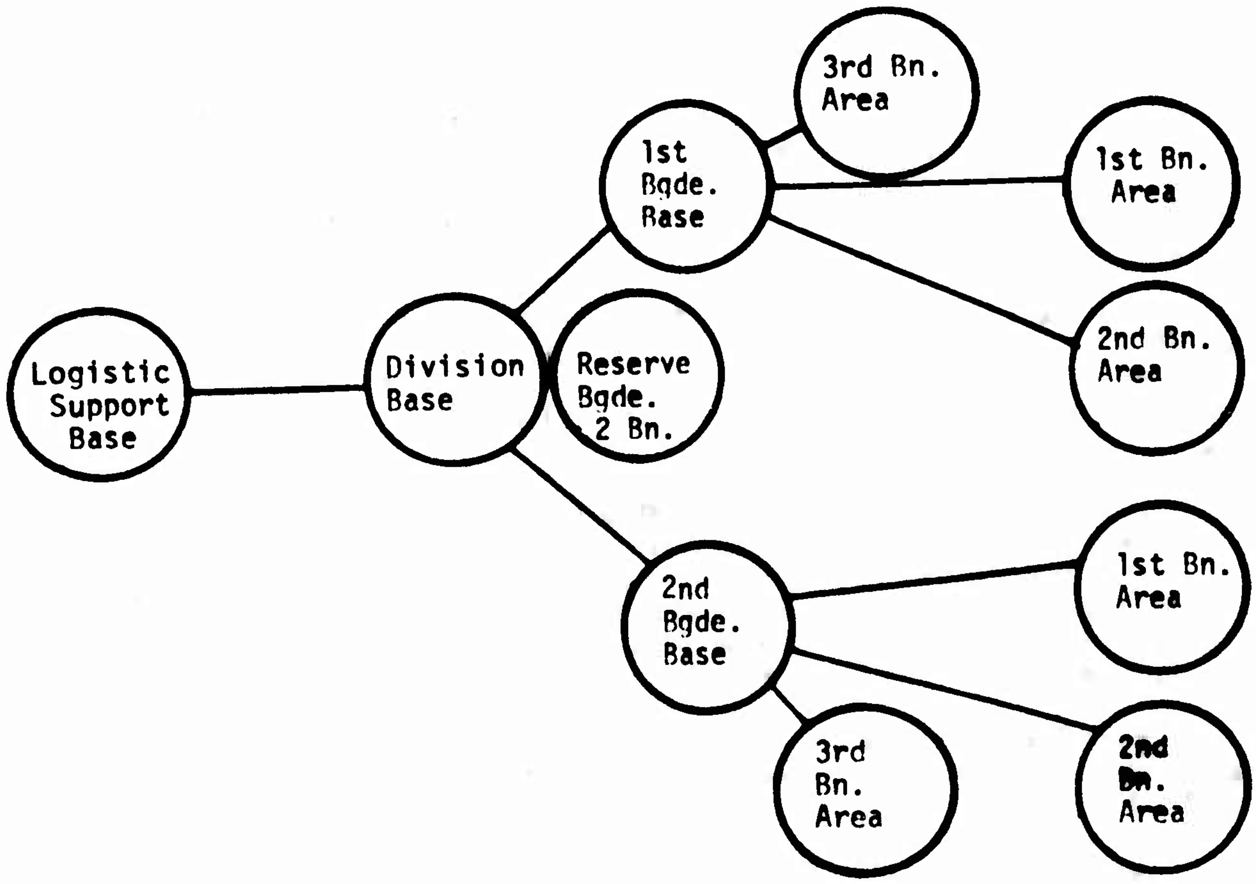

Figure 2. (C) Airmobile Division General Unit Locations. (U)

TABLE I (C)

AVERAGE AND EXTENDED DISTANCES BETWEEN UNIT LOCATIONS (U)

From	To	Distance (Nautical Miles)	
		Average	Extended
Logistic Support Base	Division Base	100	150
	Brigade Base	125	175
	Battalion Area	150	200
Division Base	Brigade Base	25	50
	Battalion Area	30	75
Brigade Base	Battalion Area	20	35

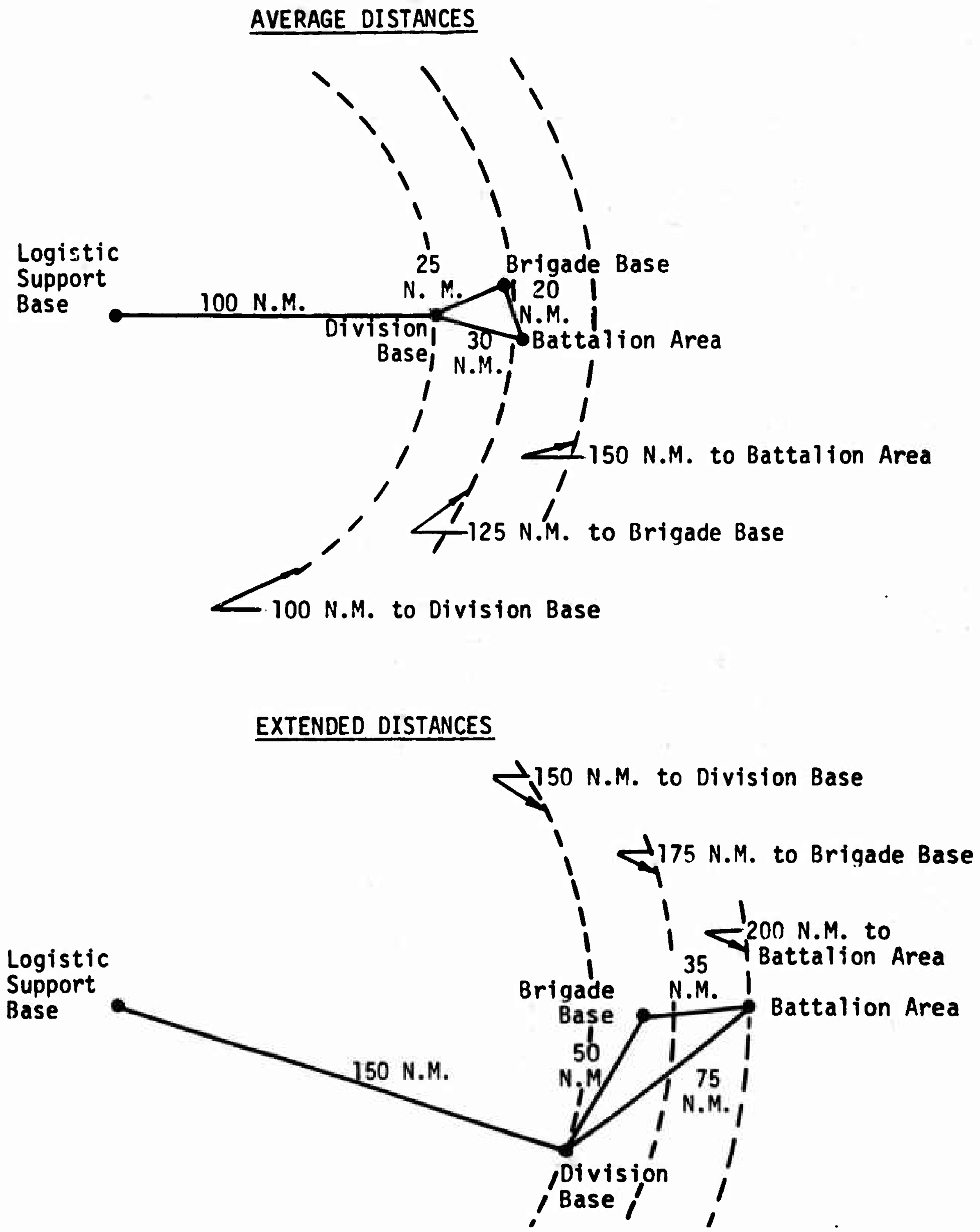

Figure 3. (C) Illustration of Average and Extended Distances Between Logistic Support Base, Division Base, Brigade Bases and Battalion Areas. (U)

(U) Within the context of this study, combat intensity determines:

1. The quantity of resupply cargo required, especially ammunition and fuel.

2. Aircraft attrition, insofar as this is affected by enemy fire.

Combat intensity can vary from a lull to a level defined by the maximum sustained rate of fire possible with the weapons possessed by the particular division involved. This study considers peacetime operations and wartime operations, including three nominal levels of wartime combat intensity: lull, normal, and maximum.

(U) As the quantity of cargo increases with combat intensity, variable operating costs increase due to the increased number of cycles required to deliver the cargo. More of the available aircraft must be assigned to the mission. Ground cargo handling time per cycle, packing and rigging required, and special handling problems vary if the mix of the cargo changes significantly with increasing combat intensity. The most important effect of increased combat intensity on the differences between the conventional and vertical/modular delivery systems is aircraft attrition. Both the probability of aircraft loss per cycle and the total number of cycles increase as combat intensity increases.

(C) OPERATIONS (U)

The tasks assumed to be performed by the air transportation systems discussed in this study include scheduled resupply, emergency resupply, transporting retrograde cargo, deployment of brigade base and battalion area units, and general support missions.

As shown in Figure 4, this study assumes that the forward-area transportation systems discussed participate in three primary operations:

1. Major deployments — defined as any movement in which the division base and all division elements are moved.

2. Tactical redeployments — defined as any movement of combat elements of the division without moving the division base location. These may be regarded as shifts of committed units within the same general geographic area.

3. Resupply operations — defined as the delivery of supplies to brigade base and battalion area units. The quantity of cargo transported depends on the units supported and combat intensity. The desired resupply frequency is dependent on the rate of movement of the unit, as well as the capability of the unit to store, transport, and redistribute the supplies delivered. For this study, resupply is assumed to be the primary mission of the aircraft.

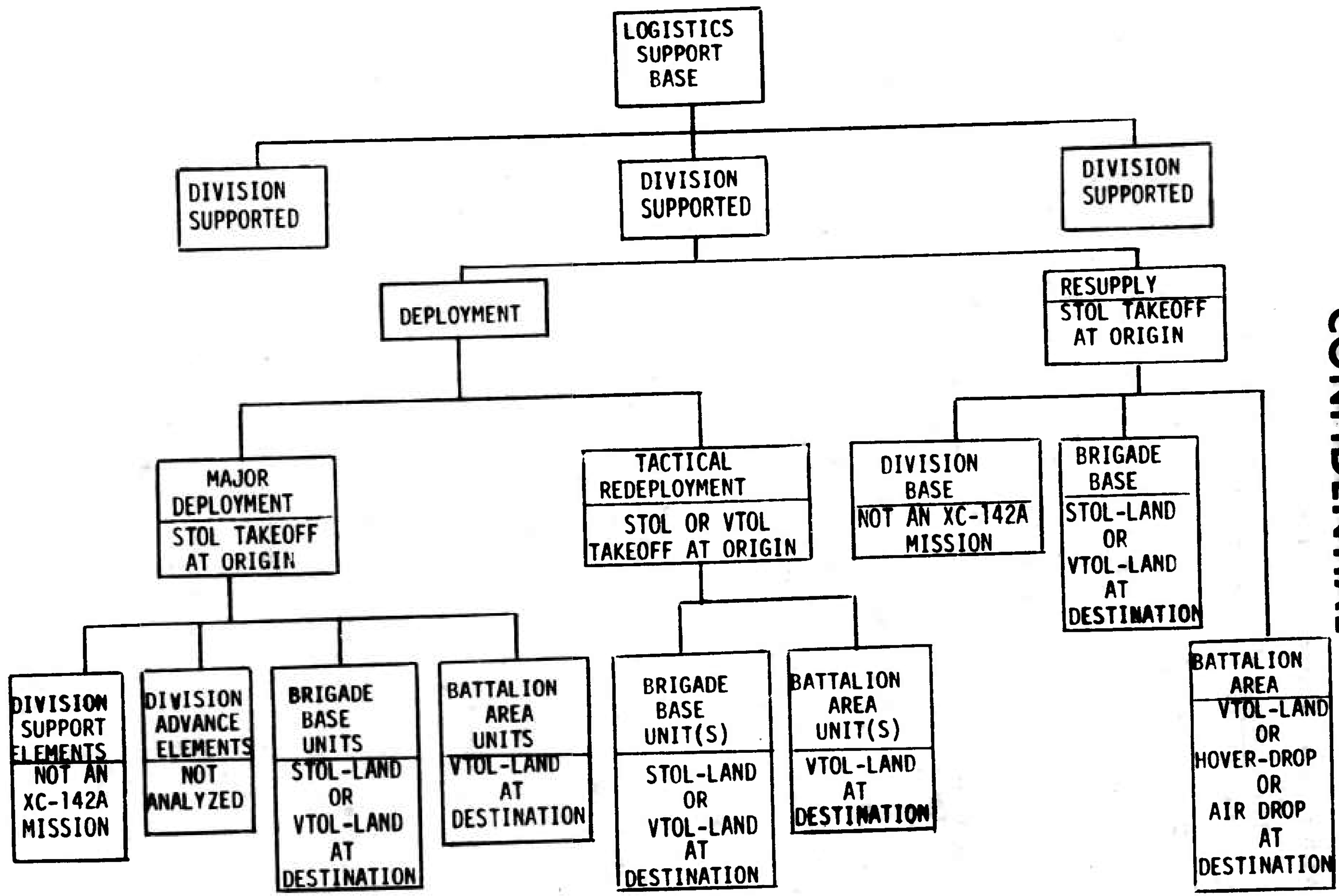

Figure 4. (C) Major Deployment, Tactical Redeployment, and Resupply Operations, Showing Delivery Modes Employed in Evaluation. (U)

(C) DEPLOYMENT (U)

(C) Major deployments of division base units are not considered in this study because the division base cargo transportable in the XC-142A and similiar-size vehicles is transported during deployments of brigade area units. In addition, it seems reasonable to assume that at least a rough field will be available at or near the division base and that by the time a new division base area is secured and division base support units are moved, it will be possible to land a larger, more productive, advanced-STOL aircraft.

(U) Major deployments to large established bases are not considered in this study. By definition, all major deployments are to forward combat areas.

(U) Tactical redeployments differ from major deployments in that the distances are shorter and the frequency of occurrence is greater.

(C) Airfield availability not only is a function of whether an airfield is in existence or not, but also is a function of the condition of the field, the resources required to secure the strip, and the amount of time the units will be located near the airfield.

(C) Generally, at least a rough airfield could be expected at the origin for major deployments and for resupply operations. Conversely, the probability of an airfield in the battalion area is quite low for any of the three operations.

(C) During major deployments, the XC-142A will assist in moving brigade area units and then resume its primary function of resupply. The major deployment evaluation assumes that:

1. An airfield suitable for STOL takeoffs is available at the brigade bases or division base from which the deployment originates.

2. The XC-142A always lands at the destination (no airdrop), either STOL or VTOL, depending on whether an airfield is available.

(C) Concurrent with its resupply operations, the XC-142A assists organic division helicopters in tactical redeployments. The evaluation of tactical redeployment assumes:

1. Either a VTOL or a STOL takeoff at the origin.

2. A VTOL landing at the destination in all cases (no airdrop).

(U) The same military units are transported by the XC-142A in both major deployments and tactical redeployments. Resupply cargo is largely palletized or in 500-gallon fuel drums. Deployment cargo is largely troops, vehicles, and equipment. The number of vehicles and men per unit and the unit loads of supply vary widely. As mentioned previously, there is little difference between the conventional and vertical/

modular delivery systems for the deployment mission if the aircraft is volume-limited.

(C) RESUPPLY (U)

(U) Resupply and deployment operations differ in the cargo transported, distances involved, delivery modes which may be used, and the time period in which the operation should be completed.

(C) Basic to any discussion of forward-area resupply is the fact that almost all supplies enter the theater by ship or air and are stockpiled at some major supply depot or depots, called the logistic support base in this study. While C-5A and FDL-type systems may offer the theater commander greater flexibility in selecting the locations for these depots, these systems will not alter the fact that most supplies for committed divisions will pass through some logistic support base.

(C) In general, it may be said that transshipment (generally fixed-wing to helicopter) and storage of supplies between the logistic support base and the ultimate consumer are:

1. Inefficient
2. Impossible to totally eliminate

At a minimum, some reserve supply storage within the division area is required for those periods when demands exceed the transportation system capacity or response time. This increase in demand could result from increased enemy activity, or from transportation system capacity decreasing due to weather or enemy action against the system itself, or both.

(C) The amount of reserve supply maintained within the division area must be minimized, as it restricts the mobility of the division. The more reliable and responsive the resupply system, the lower the reserve supply required.

(C) For the airmobile division operating in a counterinsurgency environment, this study assumes that one day of supplies for the entire division will be maintained at the division base and that one additional day of supplies for each committed brigade will be maintained at each brigade base. No additional supplies will be maintained in the battalion area (Reference 1, pages 83 and 131).

(C) Transshipment of supplies between the logistic support base and the user should likewise be minimized, as it demands facilities and manpower and increases response time from the logistic support base. As stated in the following excerpts, the desired goal is clear:

> (U) All classes of supply are lifted to the division by ALOC aircraft from the supporting base (communications zone or field army) to the farthest point forward practicable; i. e. , division base,

assault brigade base, battalion, or even company area ... It is preferable, therefore, to position reserve stocks in rear areas, and develop communications and delivery capabilities to the utmost to provide instantaneous reaction to the requirements of committed combat elements (Reference 54, pages 15 - 16).

(C) Resupply is normally accomplished from the brigade base or higher echelon directly to unit locations and gun positions... The addition of the combat-service support-personnel vehicles and equipment required for the multiple handling and redistribution that would be required if delivery were made to a central point is to be avoided (Reference 1, page 131).

(C) The route systems studied do not visualize moving to the division base resupply requirements for subordinate elements. Except for safety levels, supplies are delivered directly from the logistic base to the echelon where they will be used or consumed. Exceptions... aircraft parts... potable water... safety level stocks... (Reference 1, page 93).

(U) It is not the objective which is in question, but the degree of compromise between objective and means made mandatory by current technical, environmental, and economic considerations. To understand that these limitations are in fact current, one need only contemplate the evolution of helicopter and long-range transport technology in the past decade.

(U) The concepts of direct (non-stop from logistic support base to user) and indirect scheduled resupply using present-day vehicles and a large advanced-STOL aircraft are illustrated in Figure 5. At the rate vertical-lift and high-lift technologies are evolving, it can be assumed that superior alternative vehicles could be substituted for those shown in Figure 5 in the near future, even though present-day operational vehicles would not permit efficient direct resupply except over short distances. The flexibility inherent in direct resupply when peak demands necessitate emergency resupply is shown in Figure 5.

(U) Direct versus indirect aerial resupply is essentially a question of optimizing the possible combinations of STOL, V/STOL and VTOL vehicles. The major parameters involved are the size, speed, payload/radius capability, and cost of the numerous alternatives. Quantitative examination of direct versus indirect resupply is beyond the scope of this study.

(C) Transshipment is inherently reduced by direct resupply. With direct resupply, overall division reserve storage could be reduced and division mobility enhanced, since emergency resupply can originate at the logistic support base instead of within the division area.

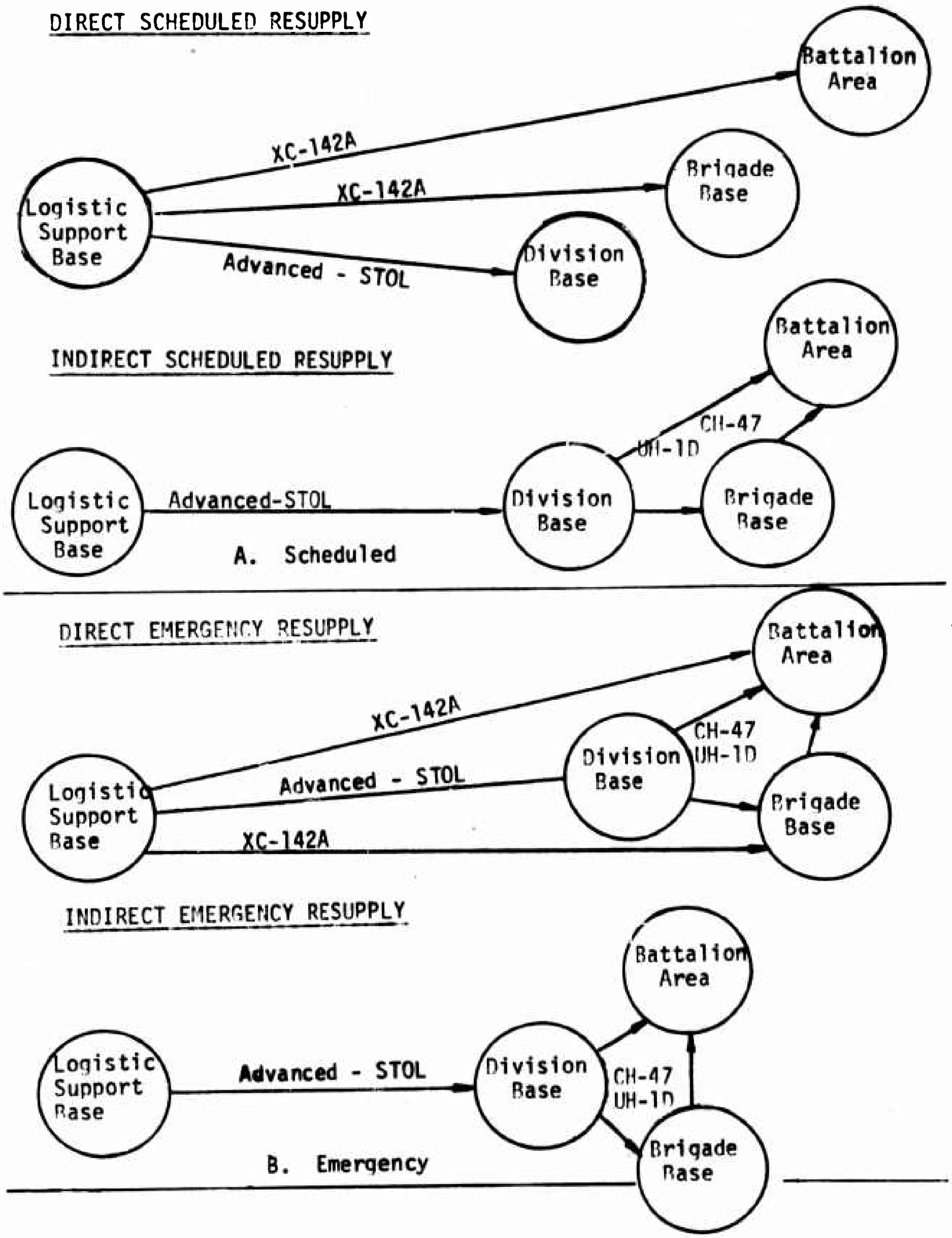

Figure 5. (C) Emergency Direct Versus Indirect Resupply. (U)

(U) The operational concept for this study is based on direct resupply. Due to its size in relation to division base requirements, the XC-142A is not used to resupply the division base in this study. A larger V/STOL would probably service the division base as well as the brigade areas if such a vehicle should become operational in the future.

(C) The resupply evaluation assumes that:

1. An airfield is always available at the logistic support base.

2. A large advanced-STOL supports the division base.

3. The XC-142A always lands at the brigade base, either STOL or VTOL, depending on whether an airfield is available.

4. No airfields are available in the battalion area, and no area suitable for a VTOL landing is available in some cases. When no landing area is available, supplies must be delivered by either airdrop or hover-drop.

The airfield and landing area terrain assumptions are discussed in greater detail in the Wartime Evaluation Mission chapter.

(U) The Army defines five classes of resupply cargo. Class I is rations and water. Classes II and IV include chemical, engineer, medical, ordnance, quartermaster, signal, and transportation supplies. Class III is fuel and lubricants, including JP-4, aviation gasoline (AVGAS), motor gasoline (MOGAS), and diesel fuel. Class V is ammunition. Classes IIIA and VA indicate aviation fuel and ammunition respectively.

(C) Classes I and V, as well as some Class II and IV and Class III cargo, are palletized on standard Army 40- x 48-inch wooden pallets. Most of Class III cargo is for use in vehicles and aircraft and is transported in 500-gallon fabric fuel drums, 55-gallon drums, and 5-gallon jerry cans. The 500-gallon fabric drums have a towbar and can be towed for short distances. The bulk of the resupply cargo is Classes III and V for combat operations. Both of these classes are quite sensitive to combat intensity. Some supplies are carried on the vehicles during deployment operations. Few vehicles or troops are carried during resupply operations.

(U) The influence of the cargo carried on cargo handling equipment design is examined in detail in subsequent chapters.

(C) DESIGN REQUIREMENTS (U)

(U) The design requirements were established in response to the operational concept of the vertical/modular delivery system. The operational concept has established the types of cargo to be transported and the delivery methods to be employed. The objective of this chapter is to examine the operational concept data in detail to determine the functional requirements of the final design. These functional requirements can be categorized by cargo characteristics, delivery mode, and general requirements.

(C) CARGO CHARACTERISTICS (U)

(U) The vertical/modular cargo delivery system must accommodate resupply cargo and must be compatible with other missions.

(C) Resupply Cargo (U)

(U) The kind of resupply cargo is determined by the units supported. The basic requirements are for food, ammunition and fuel. As outlined in the "Operational Concept" chapter, an aircraft the size and with the capability of the XC-142A would be used to support military units which operate in areas highly dependent on an air line of communication (ALOC). The airmobile division is such a division. The portions of the division supported by the XC-142A would be the combat brigades. The individual units which make up the combat brigades are defined in Appendix I.

(U) An examination of the Tables of Organization and Equipment (TOE's) for the combat brigade units was conducted. Data was compiled on the number of men, the number of types of vehicles and the number of types of weapons for each unit. From the makeup of the units, data was developed on the characteristics of the resupply cargo necessary to support them. This data is summarized in Appendix I.

(U) With the types and quantities of resupply cargo established, an investigation was made to determine the methods used to package the cargo and the size of individual cargo modules. Data on the packaging of combat rations was obtained through conversations with personnel at the Defense Subsistence Agency in Chicago, Illinois. Data on the packaging of ammunition was obtained from reference 23, "Carloading, Truckloading and Storage of Detailed Palletized Unit Loads of Boxed Ammunition and Components", which was recommended by personnel from both Picatinny and Frankford Arsenals. This document defines the manner in which manufacturers will package ammunition for shipment to the Army. This document was instrumental in establishing the size and weight of cargo modules and states in part:

> "All units shown herein are prepared to meet the following requirements:
>
> A. Gross weight approx 2000 lb, not to exceed 2200 lb.

B. Height of pallet and load not to exceed 52 inches.

C. Standard pallet 40" x 48" (whenever feasible) - - - ."

(U) The maximum size of the primary cargo module is 43 inches wide by 52 inches long, including overhang, by 52 inches high. The system must be designed to accommodate cargo modules of this size. In addition to the primary cargo module size, the system must accommodate composite pallet base up to 48 inches wide by 56 inches long, including overhang and fabric fuel drums per MIL-D-23119. which are 48 inches in diameter and 80 inches long. These larger items can be accommodated in two adjacent (40- x 48-inch design bases) pallet locations.

(C) Although the maximum weight is defined in Reference 23, the aircraft is affected by the total weight of all cargo modules carried. That is, to design the aircraft to efficiently transport a total load of maximum weight modules would result in excess capacity, and therefore inefficient operation, if any of the cargo modules weighed less than the maximum. Figure 6, which was constructed from data in Appendix I, illustrates the wide range of cargo weights which must be transported. Even the "average" cargo weight will vary, depending upon the delivery site of the supplies. The "average" weight varies from 1610 pounds at the brigade base to 1970 pounds in the battalion area. The latter number is heavily influenced by 105 mm ammunition, and is only 1520 pounds if 105 mm ammunition is excluded. Although the "average weight" cargo module may never exist, it must be defined to establish the design requirements. For this analysis, a module weight of 1740 pounds was selected, based on the average weight of all palletized cargo being delivered into the brigade area as shown by Figure 6.

(C) Also shown in Figure 6 is the fuel required to support operations of the combat brigade. It is apparent that the 500-gallon fuel drum, which occupies the place of two cargo modules, is just over the weight of two average cargo modules. The distribution of pallet weights from Figure 6 and the actual values selected for use in the evaluation are summarized in Table II.

(C) The 1740-pound cargo module, as defined above, is the average weight of the cargo only. This must be increased by the weight of the wooden pallet, the packaging, and the rigging required for a particular delivery mode. Table III defines the design point average packaged cargo module weight by delivery mode which will be used to determine the number of pallet locations required, and the maximum packaged module weight which will determine the strength of the structure and mechanism of an individual pallet location. The fuel drum data is not included, as the cargo module will govern the design.

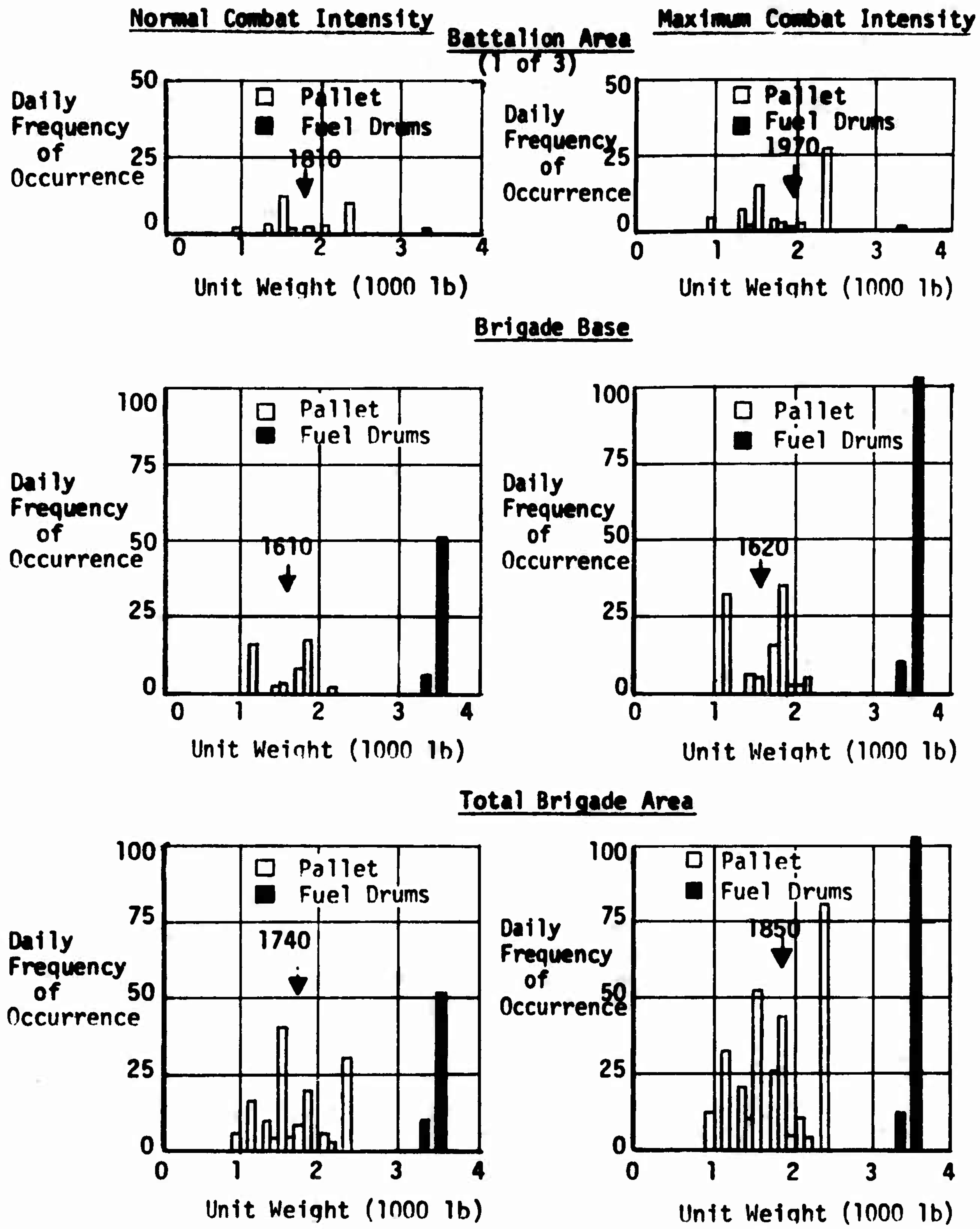

Figure 6. (C) Distribution of Pallet/Fuel Drum Weights for Battalion Area, Brigade Base, and Total Brigade Area. (U)

TABLE II (C)
DAILY RESUPPLY CARGO CHARACTERISTICS (U)

	Battalion Area		Brigade Base		Brigade Area	
	Number Nor/Max*	Average Weight (lb) Nor/Max*	Number Nor/Max*	Average Weight (lb) Nor/Max*	Number Nor/Max*	Average Weight (lb) Nor/Max*
105 mm Ammunition Palletized	10/27	2400	-	-	-	-
Other Palletized Cargo	21/36	1530/1520	53/98	1610/1620	-	-
All Palletized Cargo	31/63	1810/1970	53/98	1610/1620	146/287	1740/1850
MoGas 500-gallon Fuel Drums	1/1	3400	6/9	3400	9/12	3400
JP-4 500-gallon Fuel Drums	-	-	51/103	3600	51/103	3600
Value Used in Calculation of Rigging Weight						
- Palletized Cargo	-	1740	-	1740	-	1740
- 500-gallon Fuel Drums	-		-	3600	-	3600

NOTE: * Nor/Max indicates combat intensity as defined in evaluation mission chapter.

All weights exclude 40- x 48-inch pallets, plywood bases, rigging, parachutes, and cushioning; weights include fuel drum and ammunition containers.

TABLE III (C)

DESIGN POINT CARGO MODULE WEIGHTS (U)

Delivery Mode		*Weight (lb)
Airdrop	Average	2030
	Maximum	2690
Hover-Drop	Average	1881
	Maximum	2541
Air-Land	Average	1840
	Maximum	2500

*Weight includes cargo, pallet, packing and rigging.

(C) The maximum height of the primary cargo module will be 52 inches. The minimum and average heights of the cargo module were also investigated. Figure 7 shows the scatter of pallet heights from which the minimum can be defined as 16 inches and the weighted average as 33 inches. Further information if presented in Appendix I, showing that there is only a very general relationship between pallet weight and height.

(U) To determine the number of cargo modules which may be transported and thus the number of openings required, two items must be investigated. First, the space limit of the aircraft will determine the maximum number of the openings which will physically fit. In an aircraft the size of the XC-142A, this maximum is 10.

(C) Second, the number of openings provided must be compatible with the aircraft payload for the expected mission radii and the cargo which is transported. Normal resupply mission radii are defined in the operational concept. An analysis of the prevailing temperatures at various altitudes in selected underdeveloped areas of the world has established representative temperature/altitude conditions under which the aircraft might be expected to operate in an ALOC. (See "Evaluation Mission" chapter.) Data has been developed in the "Aerodynamic Performance" chapter which defines the payload/radius characteristics for an XC-142A type aircraft operating in the environment defined. All of this data has been combined in Figure 8 to aid in the selection of the number of openings which must be provided to perform airdrop and hover-drop missions. A preliminary analysis indicated that the structural weight penalty for providing openings in the bottom of the aircraft would be between 100 and 300 pounds per opening. This is shown in Figure 8 by a band for any particular set of conditions, the top of the band being for a 100-pound-per-opening penalty and the bottom of the band for a 300-pound-per-opening penalty. The graph on the left in Figure 8 shows the number of openings required for hover-drop and airdrop, at 59°F/sea level, with a 1740-pound pallet, and with two additional weight pallets for the hover-drop

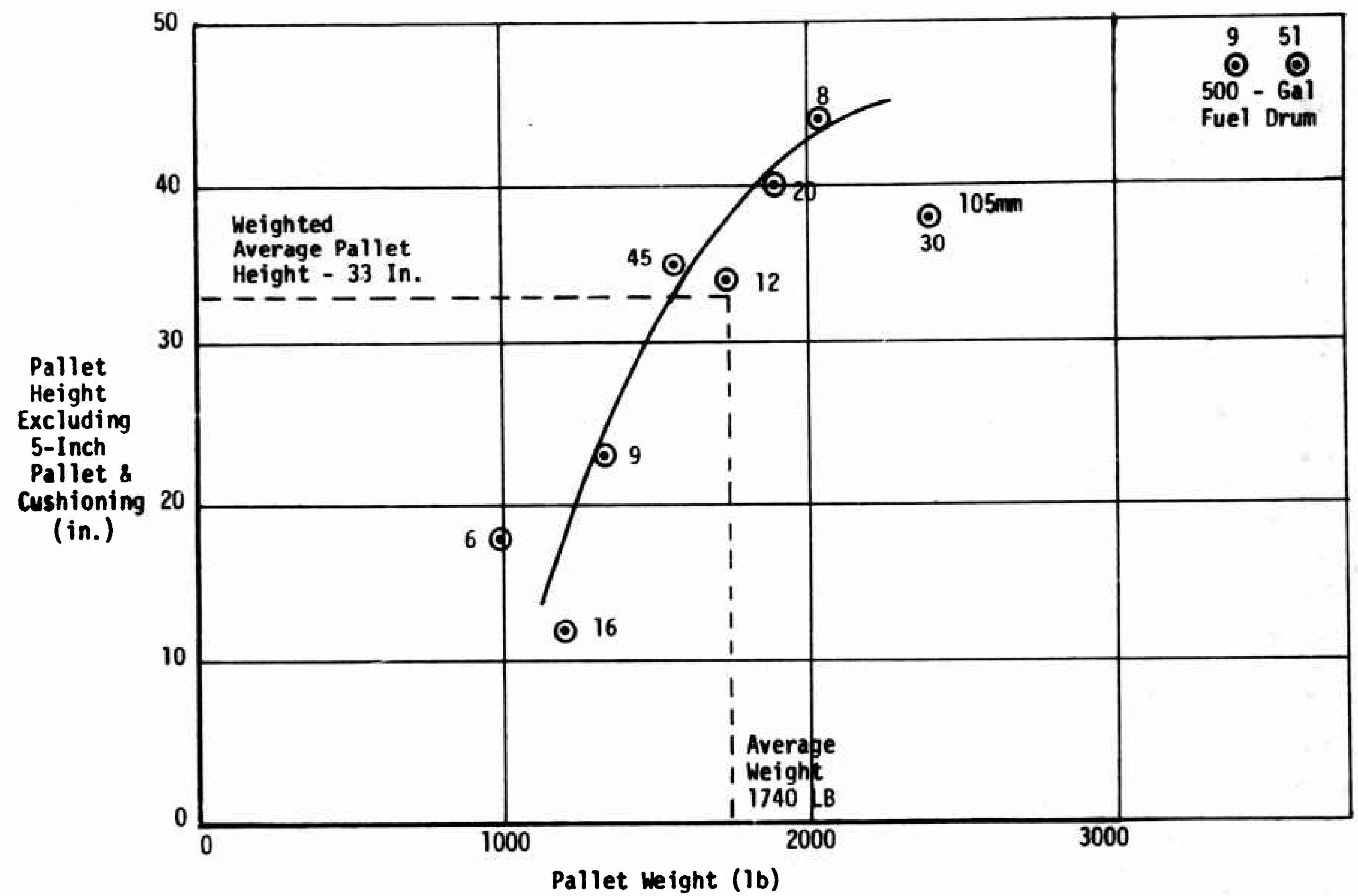

Figure 7. (C) Weighted Averages of Pallet Height versus Weight for the Brigade Area and Normal Combat Intensity by 200-Pound Pallet Weight Intervals. (U)

mode to help depict sensitivity to a change in module weight. The graph at the right in Figure 8 shows the sensitivity to varying climatic conditions for the 1740-pound module weight.

(U) Considering this information, it is necessary to select one configuration. The maximum of 10 openings is desirable to provide maximum flexibility and selectivity. However, as there is a weight penalty associated with an increased number of openings, the gain in flexibility must be assessed against the loss in productivity. Based on preliminary weight estimates for door pairs, the weight penalty of 10 openings cannot be justified. To perform the hover-drop mission requires a minimum of 6 openings, as shown in Figure 8. Six openings will limit the productivity of the aircraft in airdrop missions. The configuration with eight openings has been selected in light of the performance of the airdrop mission and the flexibility to handle a complete load of lighter than normal cargo modules. To provide eight openings in the XC-142A necessitates double rowing of cargo openings. The length of the XC-142A permits a maximum of only six openings in a single row.

(U) Other Missions

The vertical/modular cargo handling system must permit the use of the aircraft for other assigned missions with a minimum of cargo space reconfiguration. Other missions include the transport of combat troops, military vehicles and equipment, and ambulatory and litter-bound medical evacuees.

(C) CARGO DELIVERY MODES (U)

The vertical/modular cargo delivery system must provide for discharge of resupply cargo in three modes: airdrop with a forward velocity, airdrop hovering, and static on the ground.

Airdrop and Hover-Drop Delivery

The vertical/modular cargo delivery system must provide for the discharge of resupply cargo as described in the previous paragraph through an opening(s) in the bottom of the aircraft. The order in which individual cargo modules are dropped must not be restricted by the system. The bottom opening(s) must be of sufficient size to allow the cargo modules to drop without striking the aircraft primary structure. The doors which cover the bottom openings must be capable of being opened and closed at airspeeds of 120 knots and in ground effect within 5 feet of the ground.

A means must be provided to attach and retrieve the parachute static line for performing airdrop missions.

Air-Land Delivery

The vertical/modular cargo delivery system must provide for the delivery of all types of cargo by landing and unloading through the rear doors

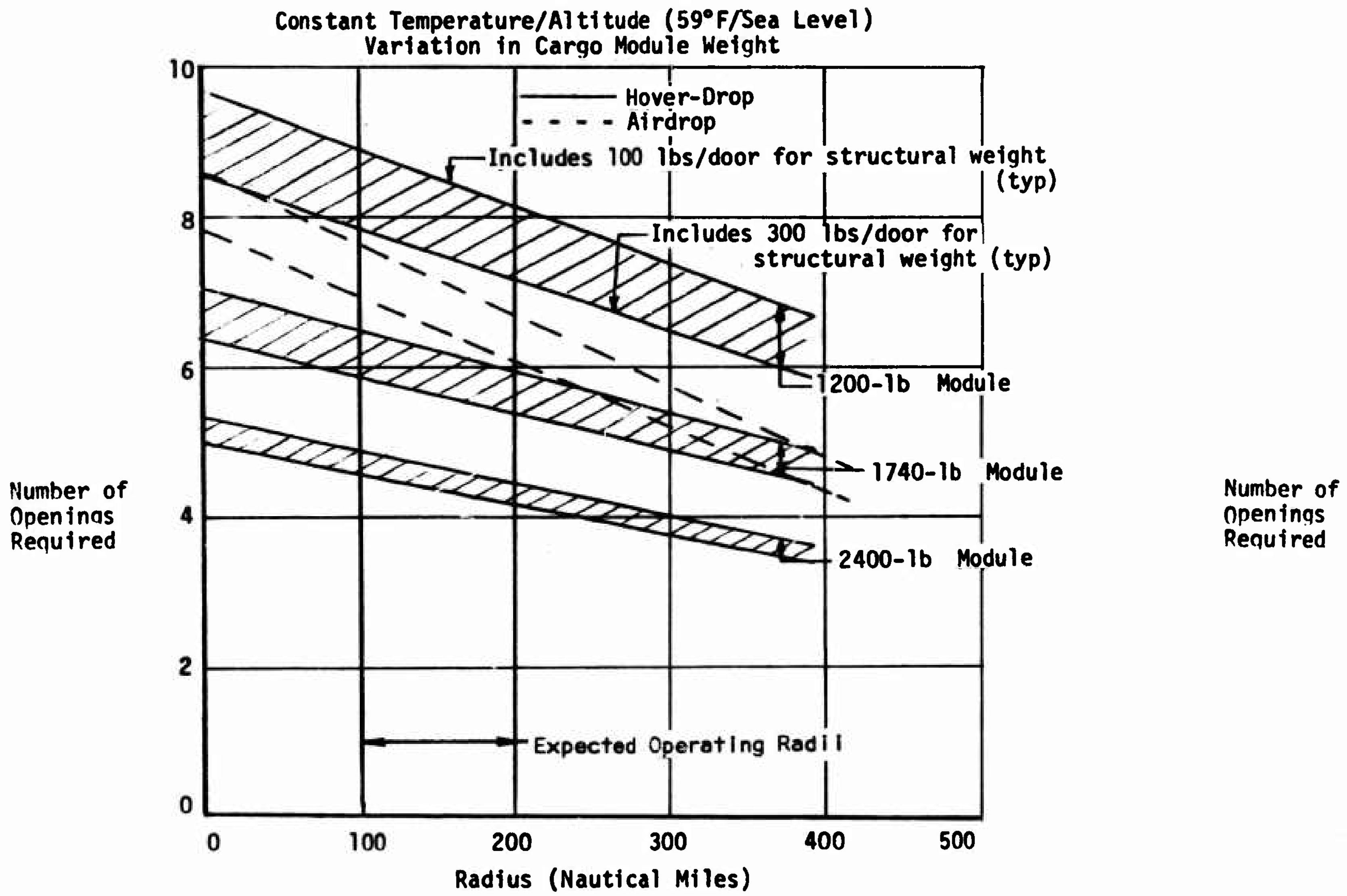

Figure 8. (C) Number of Openings versus Radius — Selected Criteria. (U)

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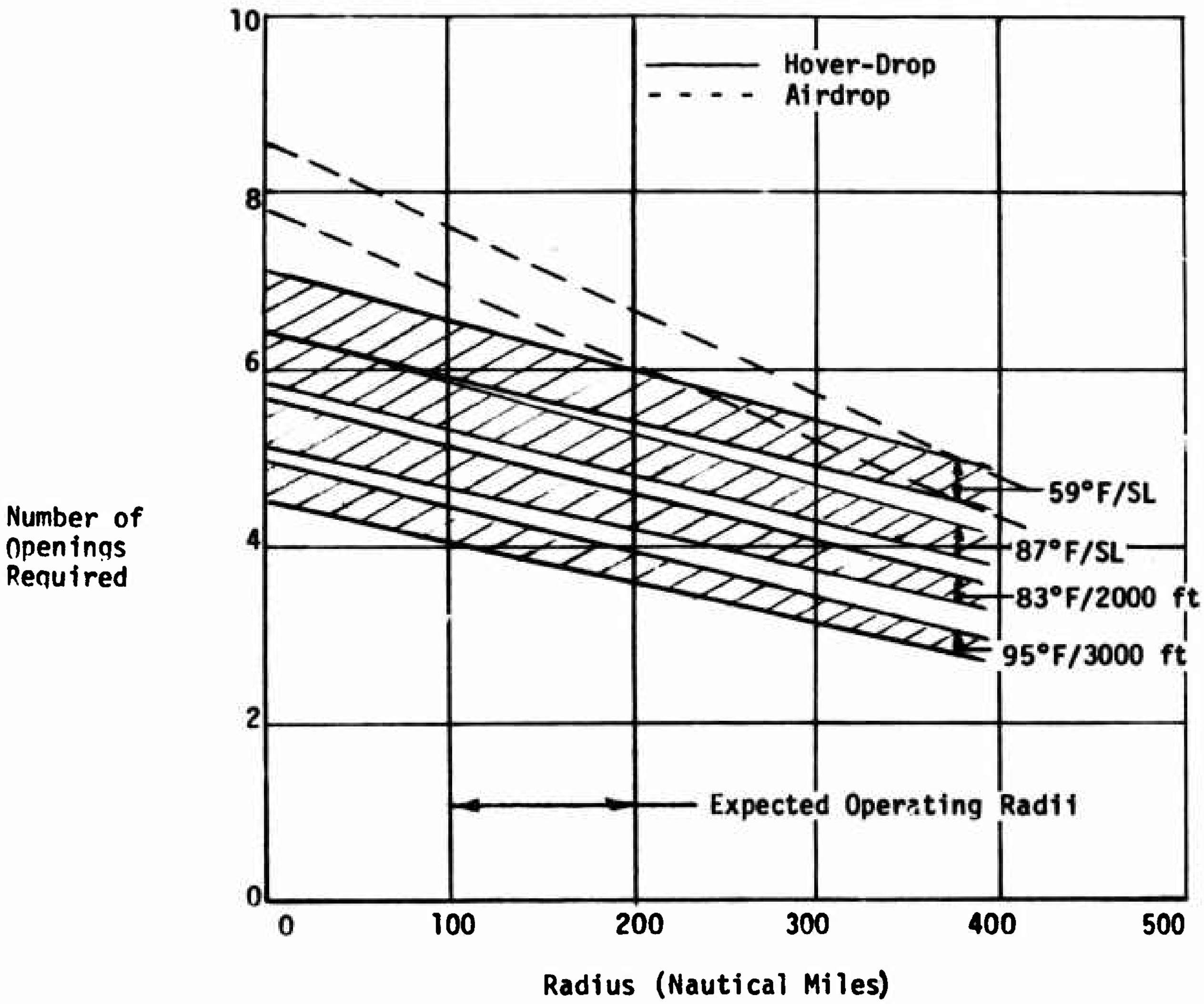
Various Temperature/Altitudes

Constant Module Weight (1740 lbs)



ria. (U)

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of the aircraft. This includes: 40-inch by 48-inch pallets, 500-gallon fuel drums, vehicles as large as a 3/4-ton truck and trailer, troops, and litter patients.

(U) GENERAL REQUIREMENTS

General requirements are those associated with the design of a cargo handling system.

Cargo Restraint Factors

The system must provide for restraint of cargo to the following load factors:

Flight Loads	Fwd, aft, lateral	1.5g
	Vertical up	2.0g
	Vertical down	4.5g
Crash Loads	Forward	8g

The restraint must be designed such that for airdrop or hover-drop delivery the cargo is held securely in place until dropped. The requirement to release a portion of the airborne restraint (as with the conventional airdrop system) prior to load release is to be avoided.

Loading and Unloading

The system should provide for the movement of cargo into and out of the aircraft with a minimum of effort (roller conveyors must be provided at a minimum). The method of restraining cargo must provide for the rapid loading and unloading of cargo.

Reliability and Maintainability

The system design must be such that the failure of the cargo drop mechanism in a single cargo module location is not catastrophic and will not prevent other modules' being dropped. Sufficient clearance and/or guidance must be provided to prevent a cargo module from jamming during the drop sequence.

The system must provide for access to critical components for maintenance and must be so designed that if the system is inoperable, the aircraft can still be utilized for missions not requiring the system. Maintenance provisions must be such that the system can be repaired with a minimum loss of aircraft availability.

System Weight

The cargo handling system must be the minimum weight consistent with fulfilling the design requirements. This is essential because the system weight will have a direct effect on the aircraft productivity due to the degradation of the aircraft payload.

(U) CONVENTIONAL CARGO HANDLING SYSTEM DESIGN

The conventional cargo handling system selected for use in the XC-124A aircraft is described in this chapter. Optimum features of several operational cargo handling systems were used in the development of the conventional cargo handling system.

DESIGN CONSIDERATIONS

The design of the components for the conventional cargo handling system is responsive to the design requirements. The basic mechanical design requirements are for cargo conveyance, cargo guidance, cargo restraint, and release of restraint for airdrop, hover-drop, and air-land missions.

The conventional cargo handling system was designed to load factors as specified by the Design Requirement chapter.

SYSTEMS CONSIDERED

Two existing cargo handling systems were considered as being representative of current state-of-the-art systems.

The first system considered was the 463L system as used in the CV-7 aircraft. The second system was the skate wheel conveyor and buffer board system currently being used in the CV-2 aircraft. The fundamental difference between these two systems is the type of cargo pallet used.

463L System

This system consists of an aircraft type roller conveyor system which is placed on the cargo floor and held in place with quick-disconnect attachments (see Figure 9). An optional installation of roller conveyors has been employed in other recent 463L delivery systems. This optional installation permits the roller conveyor sections to be inverted into recesses in the cargo floor to provide a flush surface.

The guide rails in the 463L system contain complex integral latches which engage notches in the edge of the special pallets. Mating lips on the pallets and guide rails provide vertical restraint and lateral guidance. The integral latches provide restraint of the cargo in a forward and aft direction. These latches are operated manually for latching and unlatching pallets during loading and off-loading phases of an air-land cargo mission. The operation of the latches is accomplished at a master control panel located within the cargo compartment. The mechanisms of the integral latches are designed to permit automatic release of the cargo pallet during the extraction phase of an airdrop mission.

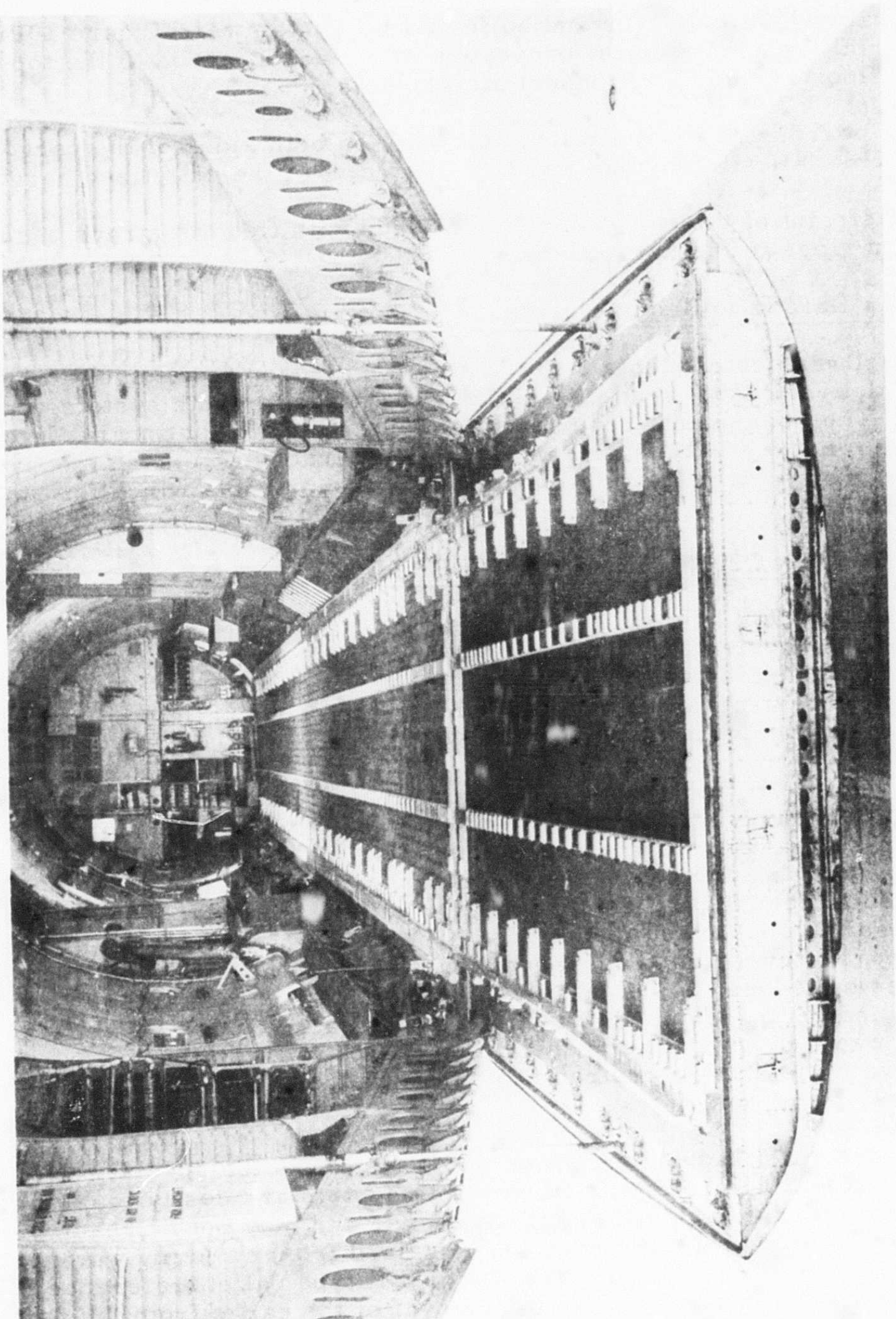


Figure 9. (U) 463L Cargo Handling System.

Skate Wheel Conveyor and Buffer Board System

The skate wheel conveyor and buffer board system (see Figure 10) uses industrial type skate wheel conveyors which are attached to the top of the cargo floor by quick-disconnect attachments.

Buffer boards are installed longitudinally on both sides of the cargo floor to provide lateral guidance and side restraint of the palletized cargo.

The restraint of the cargo is accomplished with tiedown straps secured to tiedown rings in the cargo floor.

Airdrop Hardware Requirements

The hardware components required for the airdrop function of a conventional delivery system are essentially the same for both systems considered. The components required to complete the conventional delivery system for the XC-142A are an extraction parachute release mechanism, anchor cables for parachute static line hook-up, and a winch for static line retrieval.

EVALUATION OF SYSTEMS CONSIDERED

The 463L system has advantages over the skate wheel conveyor and buffer board system. Vertical, horizontal and lateral restraint of the cargo is accommodated by guide rails with integral latches which minimize the effort required to restrain or release the cargo pallets by eliminating the need to hook up and secure tiedown straps.

The invertible roller conveyors are particularly advantageous because they permit the conveyors to remain with the aircraft at all times. As spontaneous special mission requirements arise, the roller conveyors are readily available for use. The inverting feature also reduces the time required to reconfigure the aircraft for palletized cargo and bulk cargo or passenger (troop) accommodations. The inverting of the roller conveyors may not, however, be necessary when a mission requires the transport of vehicles or troops. As shown in Figure 11, the rollers are a low-profile design and protrude only 1/2 inch above the cargo floor. The low-profile design would permit either vehicles or troops to enter the cargo compartment, with the rollers protruding, without adverse effect to the rollers, vehicles, or troops.

The prominent disadvantage of the 463L system is the special pallet requirement. The pallets used with this system are costly to fabricate, are primarily for air-land cargo missions, and may not be readily available as the need arises. Cargo, as received from an Army warehouse, is usually loaded on a general-purpose forklift type pallet (reference MIL-P-15011D). This would necessitate removal of the cargo from the forklift pallet and reloading onto the 463L pallet.

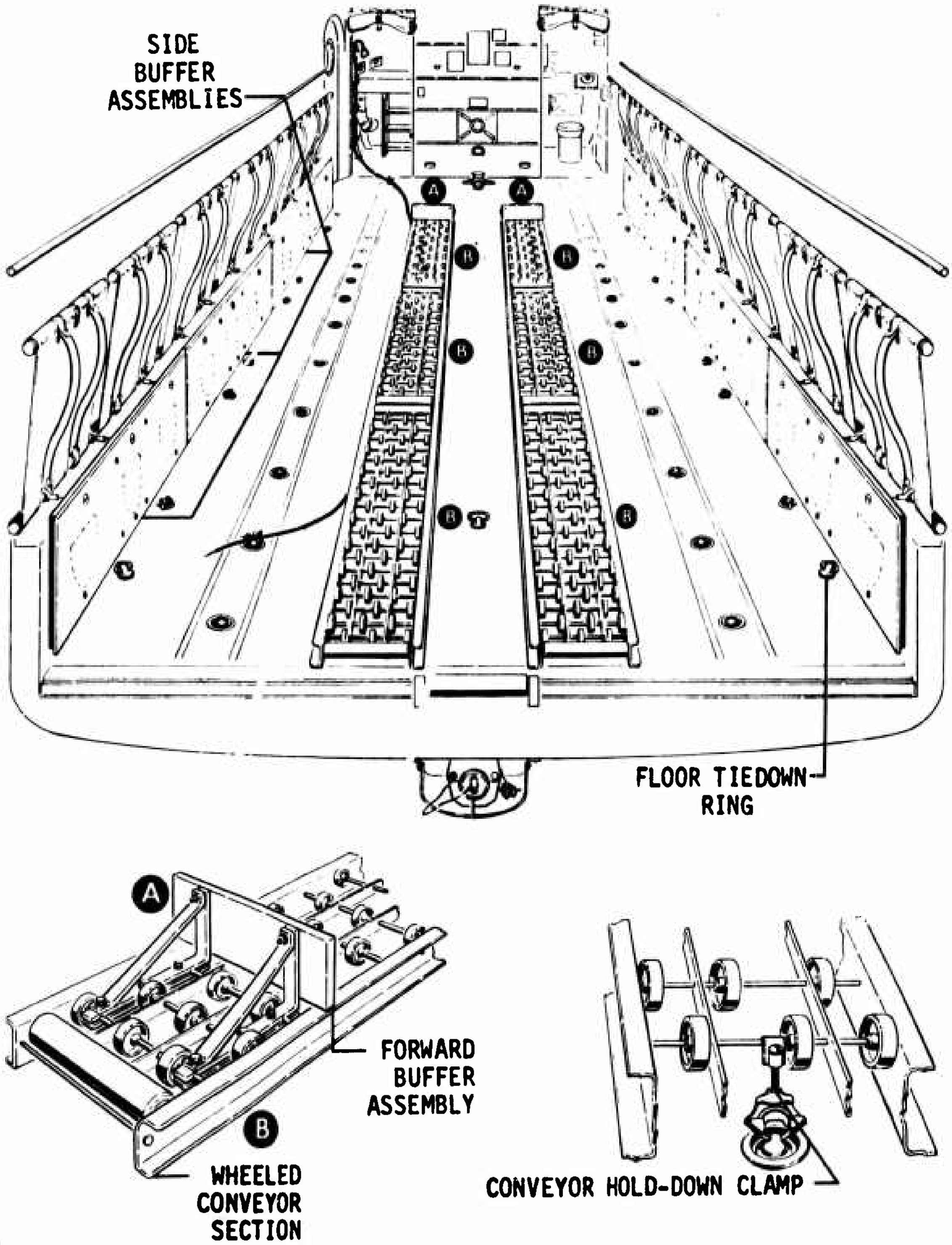


Figure 10. (U) Skate Wheel and Buffer Board System.

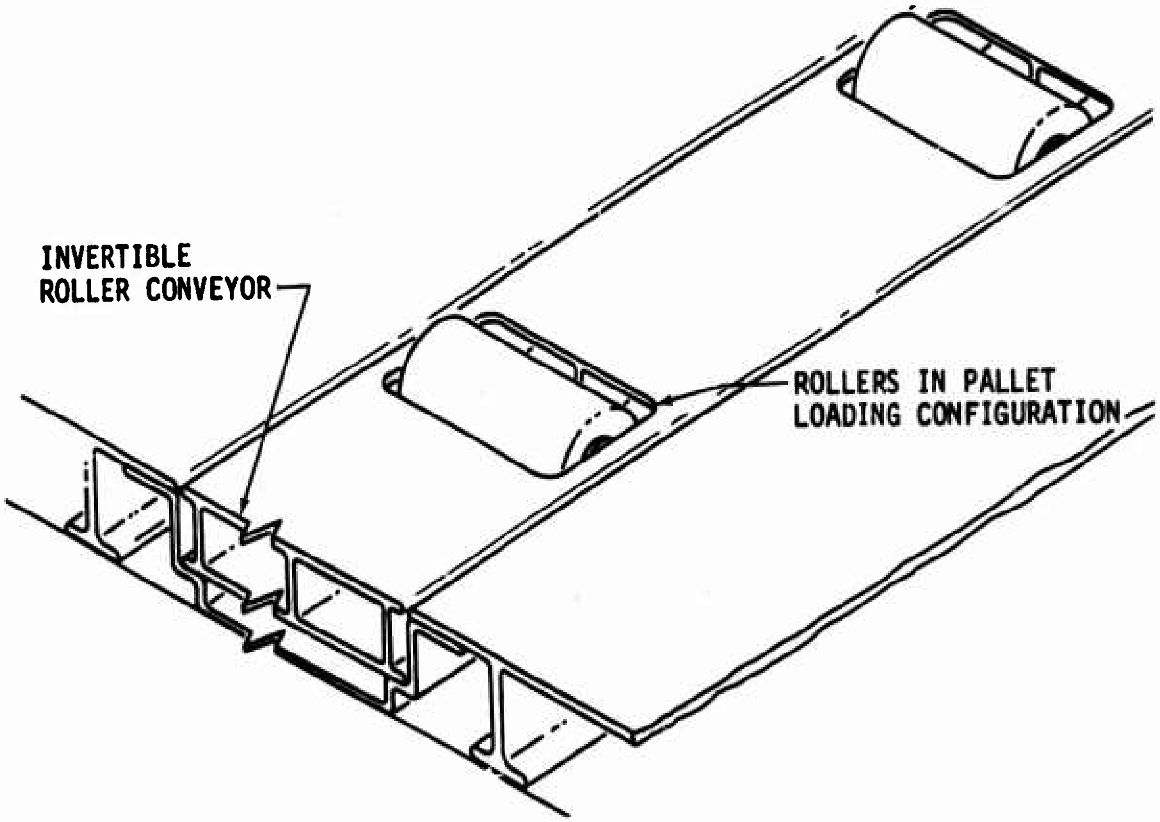


Figure 11. (U) Invertible Roller Conveyor.

The skate wheel conveyor and buffer board system has been used effectively in other aircraft. This system represents simplicity of design at minimal cost with a high degree of reliability.

The disadvantages of this system are twofold. The skate wheel conveyors, although functionally efficient, are of heavy construction since they are primarily designed for industrial use. The second disadvantage is that removal of the conveyors is required when a flush cargo floor is needed. The skate wheel conveyor sections are also cumbersome to handle because of their weight and size.

Selection of Optimum Approach

It has been determined that a combination of both systems considered would provide the desired results to obtain the highest degree of efficiency for a conventional delivery system for the XC-142A.

The invertible roller conveyors, as shown in Figure 11, are more suitable to satisfy the requirements of the XC-142A. The basis for this decision is the similarity of weight between the skate wheel conveyors and the invertible roller conveyors (see Table IV). The invertible roller conveyors have the added advantage of constant availability for spontaneous mission requirements, and aircraft floor reconfiguration can be accomplished more expeditiously with less effort.

Buffer boards have been selected for use with the conventional delivery system in the XC-142A. The primary reason for this selection is that the buffer boards do not require a specially designed pallet and will accommodate a standard general-purpose, wooden pallet with a plywood base.

DESCRIPTION OF CONVENTIONAL DELIVERY SYSTEM

The final design concept of the conventional delivery system is shown in Figure 12.

Buffer Boards

The buffer boards are constructed of 1/2-inch-thick plywood and are covered with 0.040-inch-thick aluminum sheet. They are installed longitudinally at the edge of the cargo floor and aft ramp and are equipped with integral latches.

Rcller Conveyors

Six rows of roller conveyors are provided on the main cargo floor and aft ramp to support two rows of palletized cargo (see Figure 13).

The roller conveyors are divided into sections which permit ease of handling when reconfiguring the aircraft. These sections are fabricated

TABLE IV (U)

CONVENTIONAL DELIVERY SYSTEM WEIGHT AND COST COMPARISON

Component Description	Integrated Roller Conveyor and Buffer Board		463L System-Rollers Conveyor and Guide Rails		Skate Wheel Conveyor & Buffer Board System	
	Weight (Lbs)	Cost* ($)	Weight (Lbs)	Cost* ($)	Weight (Lbs)	Cost* ($)
Buffer Boards or Guide Rails With Integral Latches	142 (5)	75 (6)	320 (7)	8000 (7)	142 (5)	75 (6)
Roller Conveyors or Skate Wheel Conveyors	522 (1)	4200 (2)	522 (1)	4200 (2)	515 (3)	510 (4)
Anchor Cable Installation	10 (9)	100 (9)	10 (9)	100 (9)	10 (9)	100 (9)
Static Line Retriever Winch	50 (10)	3000 (10)	50 (10)	3000 (10)	50 (10)	3000 (10)
Pendulum Release Mechanism	10 (8)	125 (8)	10 (8)	125 (8)	10 (8)	125 (8)
Total	734	7500	912	15425	727	3810

Note:
(1) 6 rows @ 2.5 lb/ft
(2) Estimated
(3) 3 rows @ 5.0 lb/ft
(4) \$5.00/ft
(5) 1.75 lb/ft
(6) 1.00 lb/ft
(7) Weight and cost based on information received from Brooks & Perkins Inc.
(8) Estimated
(9) Estimated
(10) Estimated
* Procurement Cost

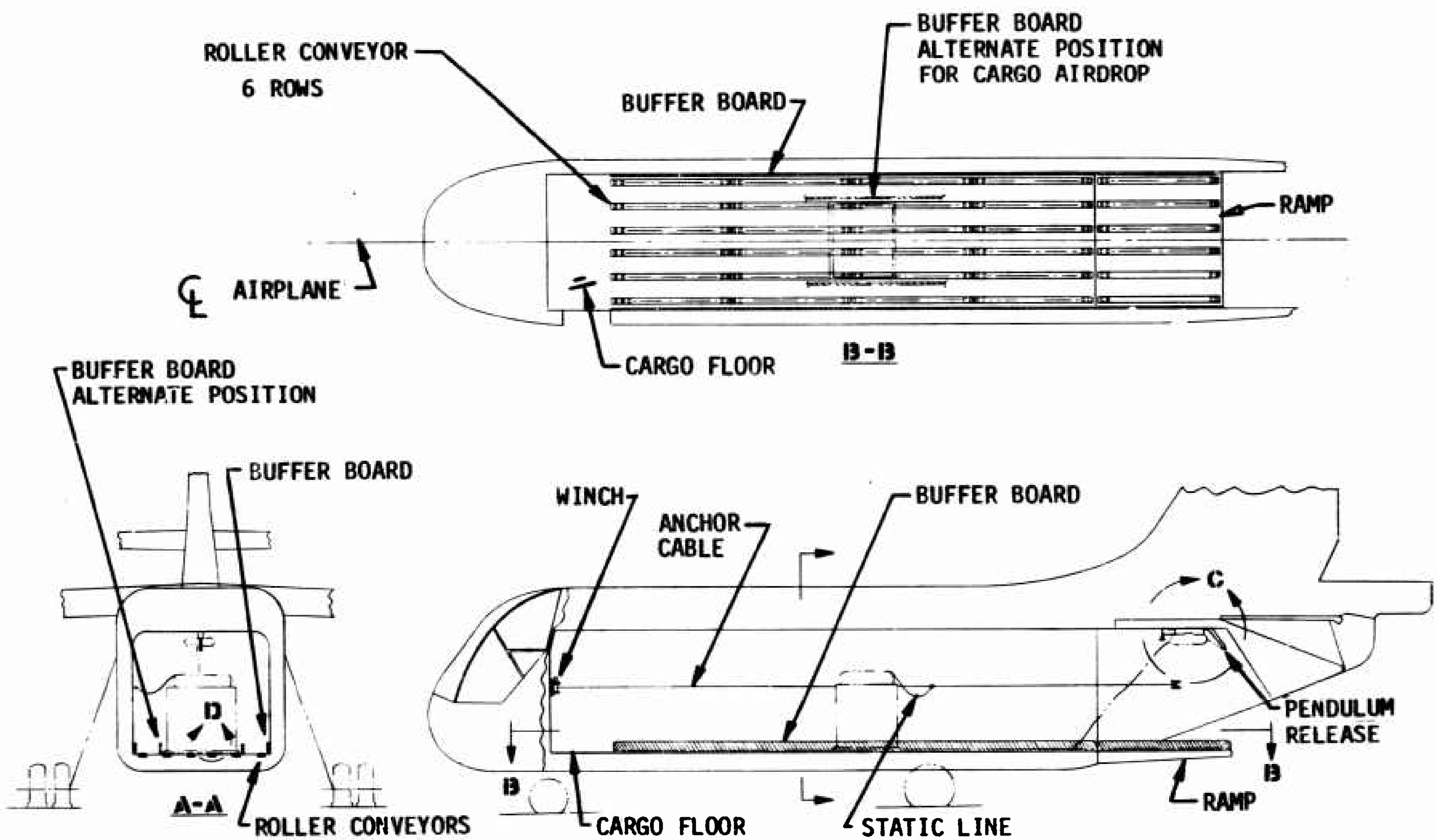


Figure 12. (U) Conventional Cargo Handling System.

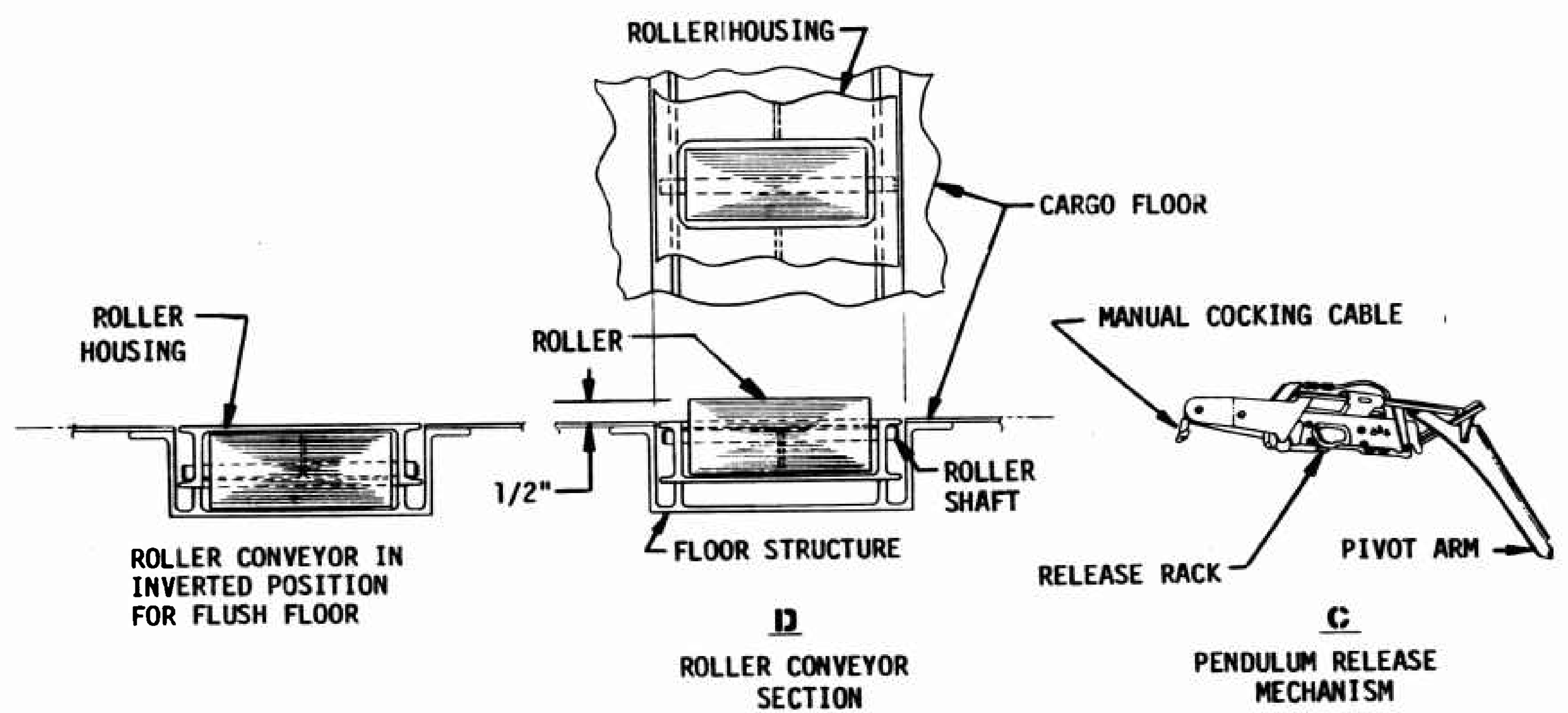


Figure 13. (U) Details of the Conventional Cargo Handling System.

from aluminum tubular extrusion, and when inverted into the floor troughs, they provide a flush cargo floor of adequate strength to support vehicles. The conveyor sections are secured to the cargo floor with mechanical latches.

The rollers are recessed in the extrusion and are spaced approximately 4 inches apart. The rollers are designed to withstand the dynamic forces imposed upon them by pallet transition during the extraction phase.

Anchor Cable

An anchor cable has been provided within the cargo compartment for parachute static line hook-up. The cable is attached to hard points on the fuselage structure.

Static Line Retriever

A commercial winch, specially designed for this function, has been provided at the forward end of the cargo compartment. It is mounted to specially designed brackets which are attached to the fuselage structure.

Restraint

The restraint of the cargo for the conventional delivery system will be accomplished with 5000-pound-capacity tiedown straps furnished with the aircraft.

Rigging procedures for restraint and release of cargo during airdrop are discussed in the Operational Comparison chapter of this report.

Pendulum Release Mechanism

An electromechanical release device to support and deploy the extraction parachute has been incorporated in this system (see Figure 13); it is commonly used in other conventional delivery systems and is identified as a "pendulum release mechanism." The pendulum release mechanism is mounted overhead in the vicinity of the aft ramp (see Figure 13). When actuated, the parachute will swing in an arc and be released into the slipstream aft of the trailing edge of the aft ramp. The electric release circuit is designed so that the device cannot be electrically released unless the cargo ramp and aft doors are open to the aerial delivery position.

(U) VERTICAL/MODU[illegible] AERIAL DELIVERY CARGO HANDLING SYSTEM DESIGN

The primary design requirement for the vertical/modular cargo handling system is to drop cargo modules through openings in the bottom of the fuselage. The first constraint imposed upon this requirement is that the vertical airdrop system must not nullify the other cargo handling capabilities of the aircraft; that is, transport of bulk cargo, air-land palletized cargo, vehicles, troops, and litter patients.

The design parameters for the vertical/modular cargo handling system have been established by the size, density and quantity of cargo specified in the Design Requirements chapter.

The elementary design requirements which must be satisfied are cargo conveyance, restraint of cargo, and release of cargo for airdrop.

Load factors that were used for the design of vertical/modular cargo handling system are as specified in the Design Requirements chapter.

DESIGN CONSIDERATION

The principal difference between a conventional cargo handling system and a vertical/modular cargo handling system is the method and direction in which the cargo is discharged for airdrop or hover-drop. The first design consideration was to determine the method for releasing and vertically guiding the cargo for airdrop or hover-drop. Cargo guidance with the conventional cargo handling system is provided by buffer boards during cargo load exit.

One solution to achieve guidance of cargo with a vertical delivery system would be to provide special cargo containers with vertical guide rails which would mate with corresponding tracks in the aircraft. This mating would increase cost and weight and would complicate loading when compared with the conventional cargo handling system. Because this solution has some undesirable aspects, a preliminary study was conducted to determine if a cargo module could be safely dropped without any guidance devices. This solution would be dependent upon the stability of the cargo module when dropped from the aircraft.

There are three factors which influence the stability of the cargo module as it is dropped.

The first factor is the center-of-gravity location of the cargo module. An ideal location would be in the geometric center of the cargo module tc provide maximum stability when dropped from the aircraft. An unsymmetrical location of the c. g. could cause the cargo to tumble. The cargo that has been considered for airdrop or hover-drop will be homogeneous, and the c. g. location would be favorable for an unguided drop.

The second factor, interdependent with the module c.g. location, is the method that is used to release the cargo modules. Preliminary investigation indicated that the most reliable method of discharging a cargo module would be to release it from a single point of support located vertically in line with the cargo module c.g.

The third factor that will influence vertical stability of a free-falling cargo module is the horizontal airstream impinging on the front of the module as it is dropped from a forward-moving aircraft. An analysis was performed to determine the amount of horizontal movement and rotation that occurred before the module dropped clear of the aircraft.

There are three variable functions which reciprocally affect vertical, horizontal, and angular movement of a free-falling cargo module: the forward speed of the aircraft, the density of the cargo, and the rectangular frontal area of the module that is directly exposed to the airstream. Vertical, horizontal, and angular movement can be determined as a function of time.

A parametric analysis was performed using the following values for each of the above variables.

Airspeed:	60, 80, 100 and 120 knots
Cargo Density:	10, 20, 30 and 40 pounds per cubic foot
Frontal Area:	Width; constant 48 inches
	Height; 40, 50, 60 and 70 inches

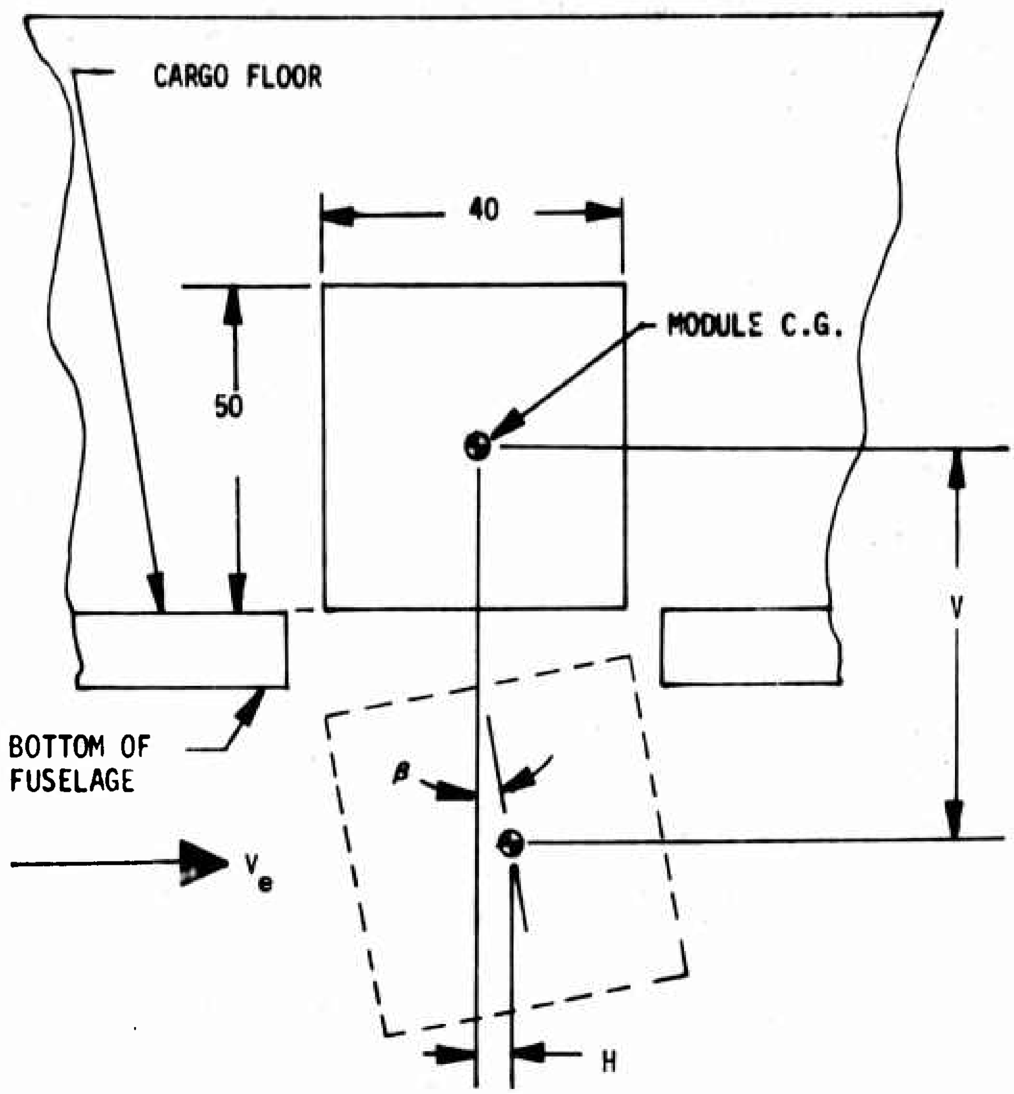
Figure 14 shows the amount of translation and rotation for a module 50 inches high, loaded with cargo of 30 psf density at an airspeed of 120 knots. These values are all conservative because (1) the cargo is rarely stacked 50 inches high, and (2) the type of cargo being delivered is usually heavier than 30 psf density.

Between time (t) 0.0 and 0.4 second after cargo release, no horizontal movement has occurred and angular rotation is negligible. This nonmotion indicates that initial vertical guidance of cargo would not be necessary. At 0.7 second after release, the cargo has cleared the aircraft.

Between 0.5 and 0.6 second after release, the cargo module could contact the aircraft structure if sufficient clearance is not provided between the cargo module and the fuselage opening. At these points in time, most of the cargo module has passed through the fuselage opening. If contact with the aircraft structure did occur, it would be a sliding action. This can be accommodated by installing antifriction devices near the edge of the fuselage opening to insure safe drop of cargo.

DESIGN CONCEPTS CONSIDERED

Several broad design concepts were investigated at the beginning of the design phase. These concepts were concerned primarily with the fundamentally important requirements to restrain cargo and to provide a single point of support and release for either airdrop or hover-drop missions.



t = Time in seconds
V = Distance in feet that module has traveled vertically at time t
H = Distance in inches that module has moved horizontally at time t
β = Angular rotation of module at time t
V_e = Velocity of free airstream

	t (SEC)							
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7
$\beta°$	0	0	0	0	1	3.5	7.5	Module has
H	0	0	0	0	0	1.2	2.76	cleared
V	0	0.24	0.40	1.4	2.6	4.0	4.8	aircraft

Figure 14. (U) Aerodynamic Effect on a Free-Falling Cargo Module.

The purpose was to generate ideas which would establish a basis for further development of the system design described in the following section.

Some of the concepts that were considered for evaluation are illustrated in Figures 15 and 16 and described in Table V.

SYSTEM DESIGNS

Three vertical/modular cargo handling systems were developed in more detail for comprehensive evaluation and selection of one for comparison with the conventional cargo handling system. Some of the features, illustrated in the design concepts, were used in the design of the three systems. These systems are identified as follows:

System I	Add-on Pallet Support Assembly
System II	Add-on Pallet Restraint Rails
System III	Integrated "T" Bar Pallet Support

Four bottom fuselage openings with eight door assemblies have been provided to airdrop or hover-drop cargo selectively with any of the three systems considered. The fuselage modification, door construction, and installation are described in the Structural Considerations chapter.

Systems I and II are removable systems which are placed on the ramp and cargo floor for airdrop, hover-drop, or transport of air-land palletized cargo. Each system is removed and stowed within the cargo compartment when transporting vehicles, bulk cargo, or troops.

System III is integrated into the ramp, cargo floor, and bottom fuselage doors and remains in place at all times. The system will accommodate any cargo mission requirement without reconfiguration of the cargo floor.

System I Description

System I is illustrated in Figures 17 and 18. Eight pairs of pallet support assemblies are positioned over each bottom fuselage door for the support of palletized air-land cargo and for the support and release of airdrop or hover-drop cargo. Each support assembly is pinned to three hinge fittings which are attached to the cargo floor lateral beams with quick-disconnect devices. (See Figure 18.) Each pair of support assemblies is coupled with an electromechanical latch as shown in Figure 18. Stabilizing beams are provided with each support assembly together with support brackets and pads (see Figure 18) to stabilize cargo when the support assemblies are resting on the bottom fuselage doors. The support assemblies hold the cargo modules after the bottom doors are opened for airdrop or hover-drop. The support assemblies are then released by the electromechanical latch, permitting the cargo to drop from the aircraft. Each support assembly is lifted up, after a cargo drop, by electric rotary actuators mounted adjacent to the center hinge fittings (see Figure 17).

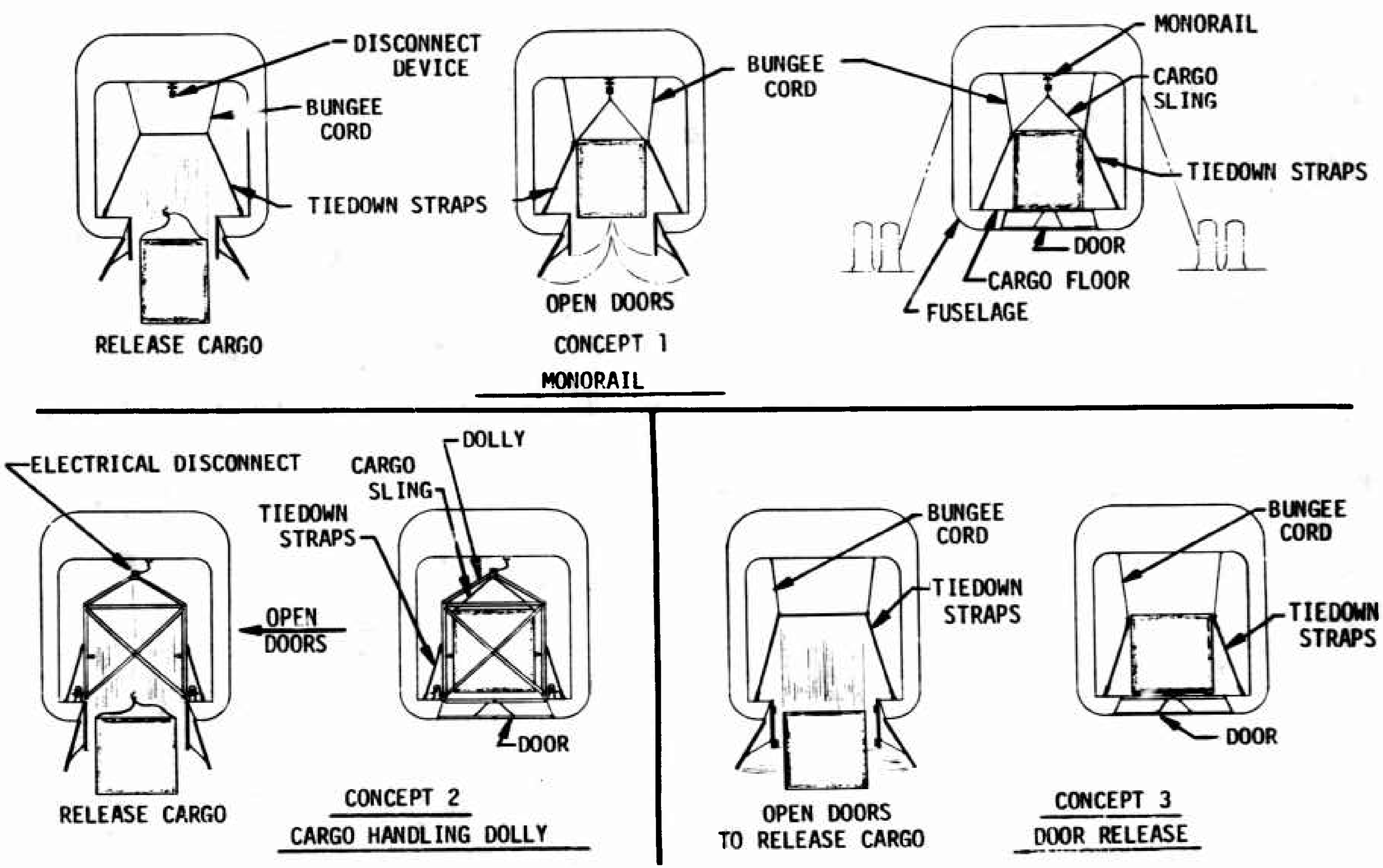


Figure 15. (U) Vertical/Modular Delivery System Concepts 1, 2, & 3.

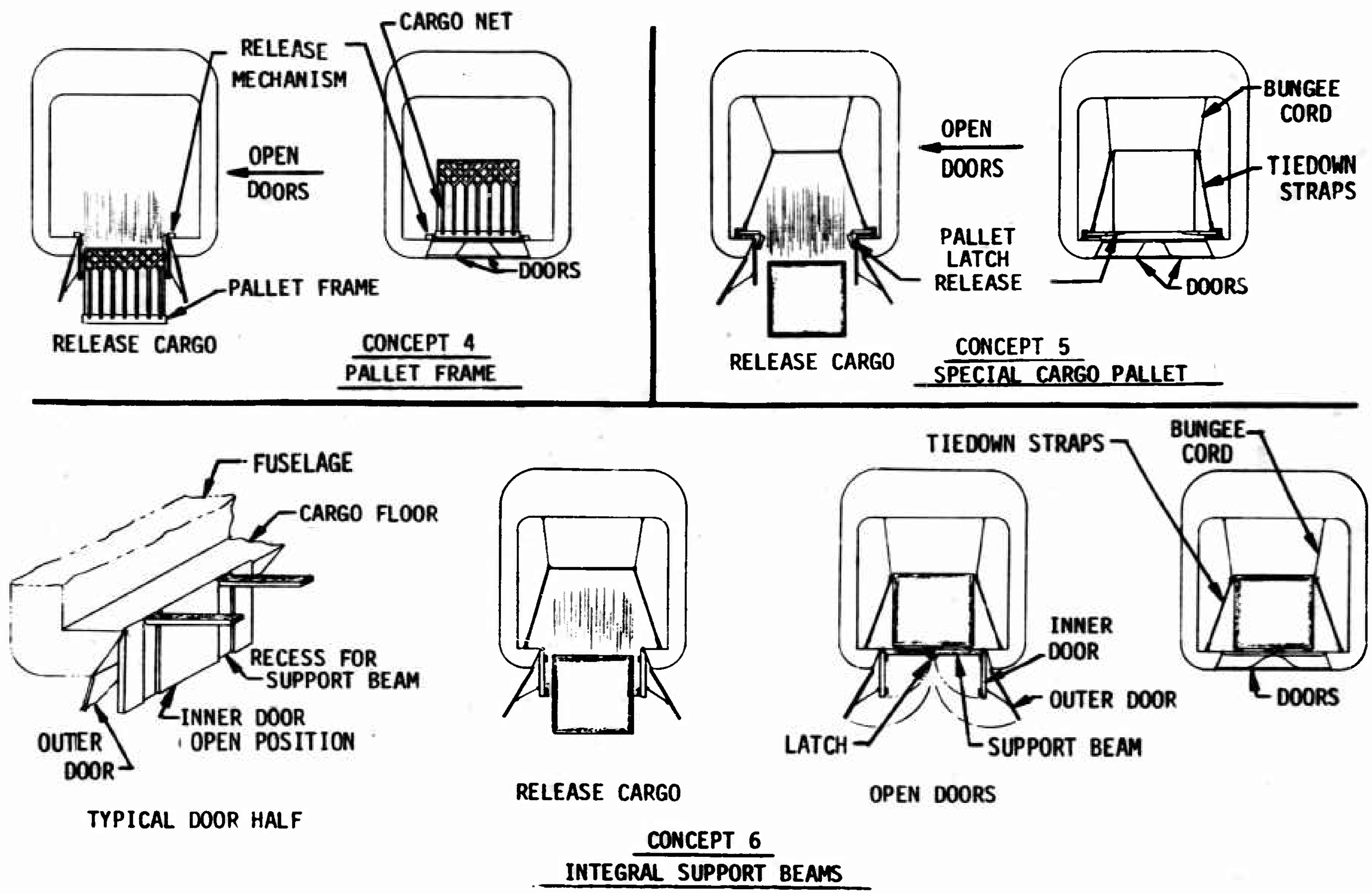


Figure 16. (U) Vertical/Modular Delivery System Concepts 4, 5, & 6.

Six rows of roller conveyors are installed on the aft ramp and aft portion of the cargo floor for movement of palletized cargo (see Figure 17).

Each row of roller conveyors is in line with the rollers installed in the support assemblies to convey two MIL-P-15011C wooden pallets side by side.

Palletized cargo is restrained for normal flight loads by restraint fittings (see Figure 18) and tiedown straps. A cargo barrier net is installed at the forward end of the cargo compartment (see Figure 17) to protect the aircraft crew from injury if cargo breaks loose from its normal restraint during a crash condition when normal load factors are exceeded.

System II Description

Vertical/modular cargo handling System II is illustrated in Figures 19 and 20.

Special preparation of cargo is required with this system for palletized air-land cargo and airdrop or hover-drop cargo. A plywood base, with protruding forward and aft edges, is banded to the module (see Figure 21).

The protruding edges of the plywood base engage the jaws in the pallet restraint rails to restrain the cargo module in the vertical and horizontal directions (see Figure 20). The jaws are closed off at each end of the restraint rail to restrain the cargo module laterally.

The restraint rails are assembled to a support housing which is attached to the cargo floor lateral beams with quick-release devices (see Figure 20). The restraint rails engage the forward and aft edges of the plywood base. Two restraint rails are used to restrain each protruding edge of the plywood base supporting a 40 x 48 cargo module. Both restraint rails are linked with a tie rod to simultaneously release both edges of the plywood base for airdrop, hover-drop, or emergency jettison (see Figure 20). The release is accomplished by a pyrotechnic rotary actuator connected to a torque tube.

The torque tube is coupled to one of the restraint rails and linked to the tie rod with a bell crank. The tie rod linkage interacts with the opposite restraint rail to insure simultaneous release of both edges of the cargo module.

Rollers are installed at the corners of the support housing to aid vertical guidance of cargo if the modules impinge on the aircraft structure during a cargo drop.

Cargo modules requiring the full width of the cargo compartment will be positioned over two bottom fuselage doors located side by side. The cargo will be restrained by four pallet restraint rails. The restraint and release function for airdrop or hover-drop will be the same as described for the 40 x 48 cargo modules except that the restraint rails will be interlocked as shown in Figure 20 to insure simultaneous release of all four restraint rails.

TABLE V (U)

DESCRIPTION AND COMPARISON OF VERTICAL/MODULAR SYSTEM DESIGN CONCEPTS

Concept	Cargo Support Mechanism	Cargo Movement	Cargo Restraint	Release Mechanism	Advantage
1	Overhead monorail. Cargo module supported by sling secured to overhead monorail.	Trolly mounted on tracks of monorail.	Tiedown straps.	Single point between apex of cargo sling and monorail.	Overhead single release mechani
2	Individual cargo handling dolly.	Cargo handling dolly.	Cargo restrained within dolly frame; dolly secured to cargo floor with tiedown straps.	Single point release at apex of dolly frame.	Single point rele mechanism; conv loading and unlo
3	Bottom fuselage doors.	Roller conveyors mounted on cargo floor and doors	Tiedown straps.	Bottom fuselage door opening cycle.	Simplicity of har less weight.
4	Special aluminum pallet frame.	Roller conveyors mounted on cargo floor.	Aluminum pallet frame supported and restrained at each corner of the frame with release mechanism mounted on cargo floor; cargo secured to pallet frame with tiedown net.	Shear pins, extending from release mechanism and into pallet frame, retracted by ignition of squibs in release mechanism.	Simplicity of car restraint; loadin unloading expedi
5	Special cargo pallet.	Roller conveyors mounted on top of cargo floor.	Cargo secured to pallet with tiedown straps; pallet secured to floor with fittings.	Cantilevered mechanical arms integrated into special pallet.	Cargo restraine prior to loading craft; time to lo and unload reduc
6	Integral lateral support beams integrated into bottom doors; two support beams required to support each cargo module.	Rollers integrated into doors and cargo floor.	Tiedown straps.	Lateral support beams hinged along same hinge line as doors. Each lateral beam consists of two arms latched at the longitudinal centerline of aircraft.	Integrated system eliminates aircr reconfiguration.

AR

Release Mechanism	Advantages	Disadvantages	Reason for Rejection
Single point between apex of cargo sling and monorail.	Overhead single point release mechanism.	Difficult loading & concentrated loads in airframe.	Difficult loading & unloading.
Single point release at apex of dolly frame.	Single point release mechanism; convenient loading and unloading.	Special handling equipment (dolly) system too heavy.	Weight; special equipment requirement.
Bottom fuselage door opening cycle.	Simplicity of hardware; less weight.	Door actuation not quick enough to let cargo module free-fall.	Door actuation not quick enough.
Shear pins, extending from release mechanism and into pallet frame, retracted by ignition of squibs in release mechanism.	Simplicity of cargo restraint; loading & unloading expedited.	Multiple release points; special equipment required (pallet frame).	Multiple release point & special equipment requirements.
Cantilevered mechanical arms integrated into special pallet.	Cargo restrained prior to loading aircraft; time to load and unload reduced.	Costly pallet construction; weight; special pallets.	Cost, weight, and special equipment requirements.
Lateral support beams hinged along same hinge line as doors. Each lateral beam consists of two arms latched at the longitudinal centerline of aircraft.	Integrated system eliminates aircraft reconfiguration.	Multiple release points.	Multiple release points.

2

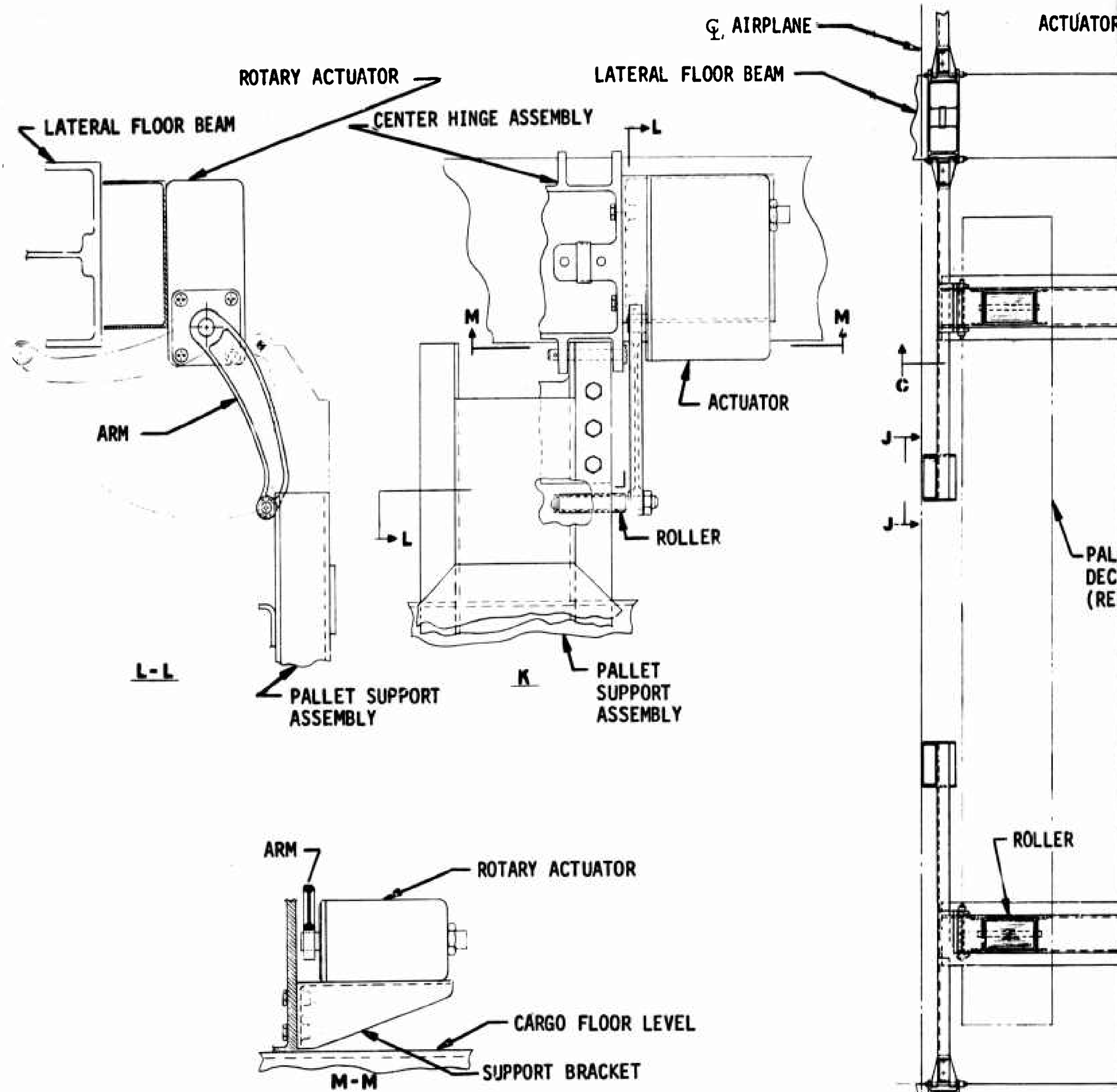
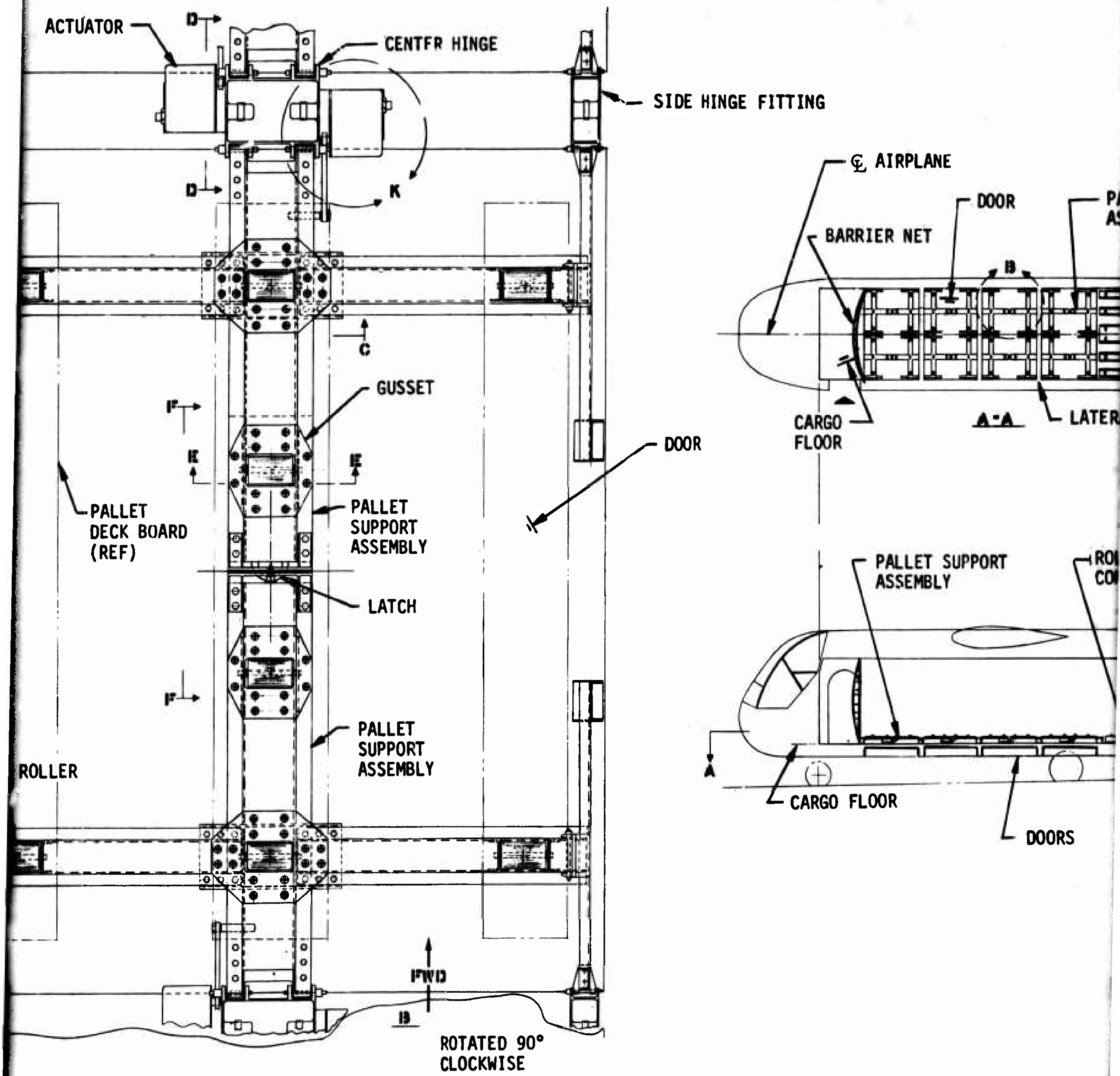


Figure 17. (U) General Arrangement of V/M Cargo Handling System I – Add-on Pallet Support Assembly.



ACTUATOR
CENTFR HINGE
SIDE HINGE FITTING
D
K
℄ AIRPLANE
DOOR
BARRIER NET
B
C
GUSSET
F
E
CARGO FLOOR
A-A
DOOR
PALLET DECK BOARD (REF)
PALLET SUPPORT ASSEMBLY
LATCH
PALLET SUPPORT ASSEMBLY
ROLLER
A
CARGO FLOOR
DOORS
FWD
B
ROTATED 90° CLOCKWISE

2

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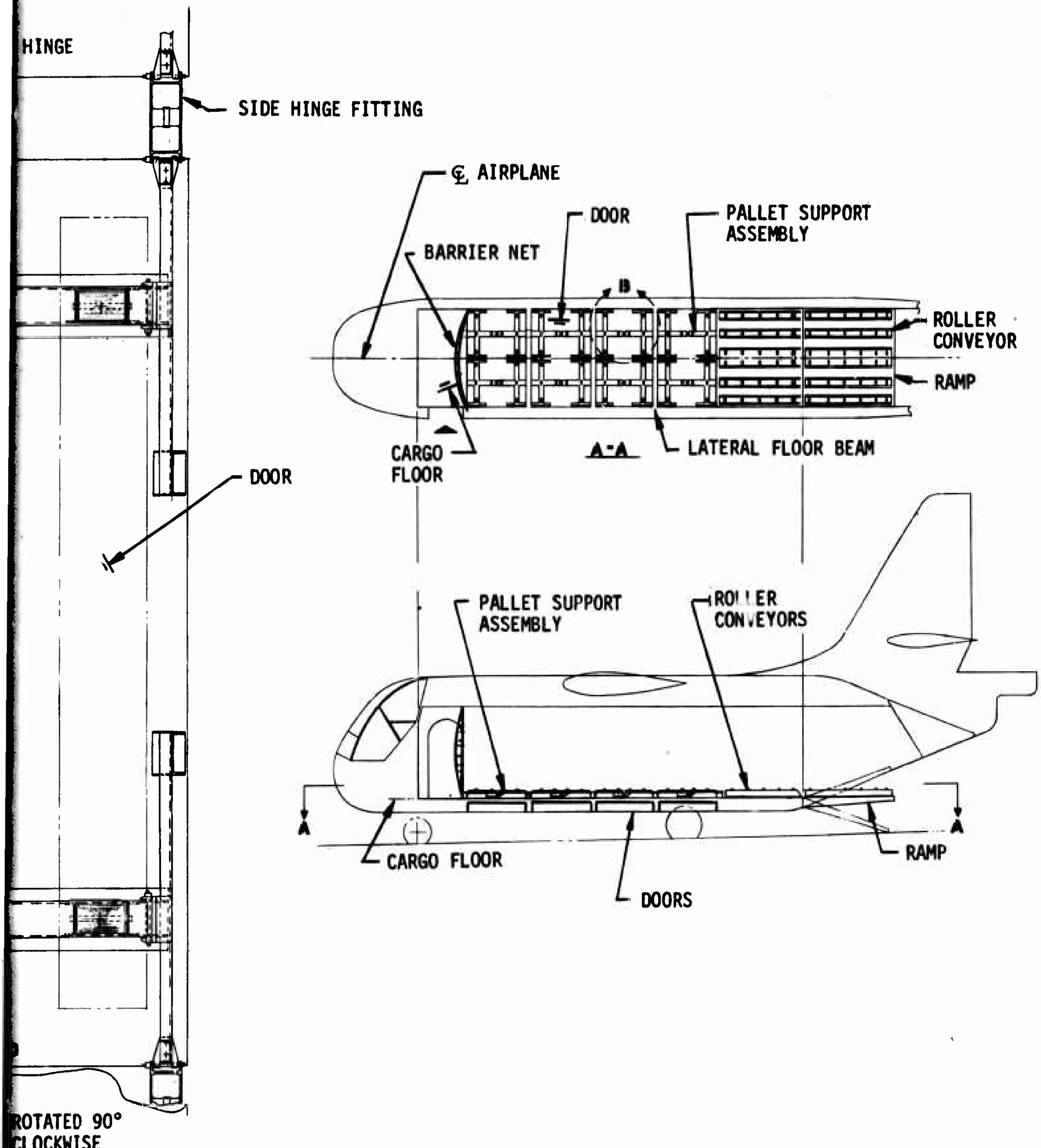


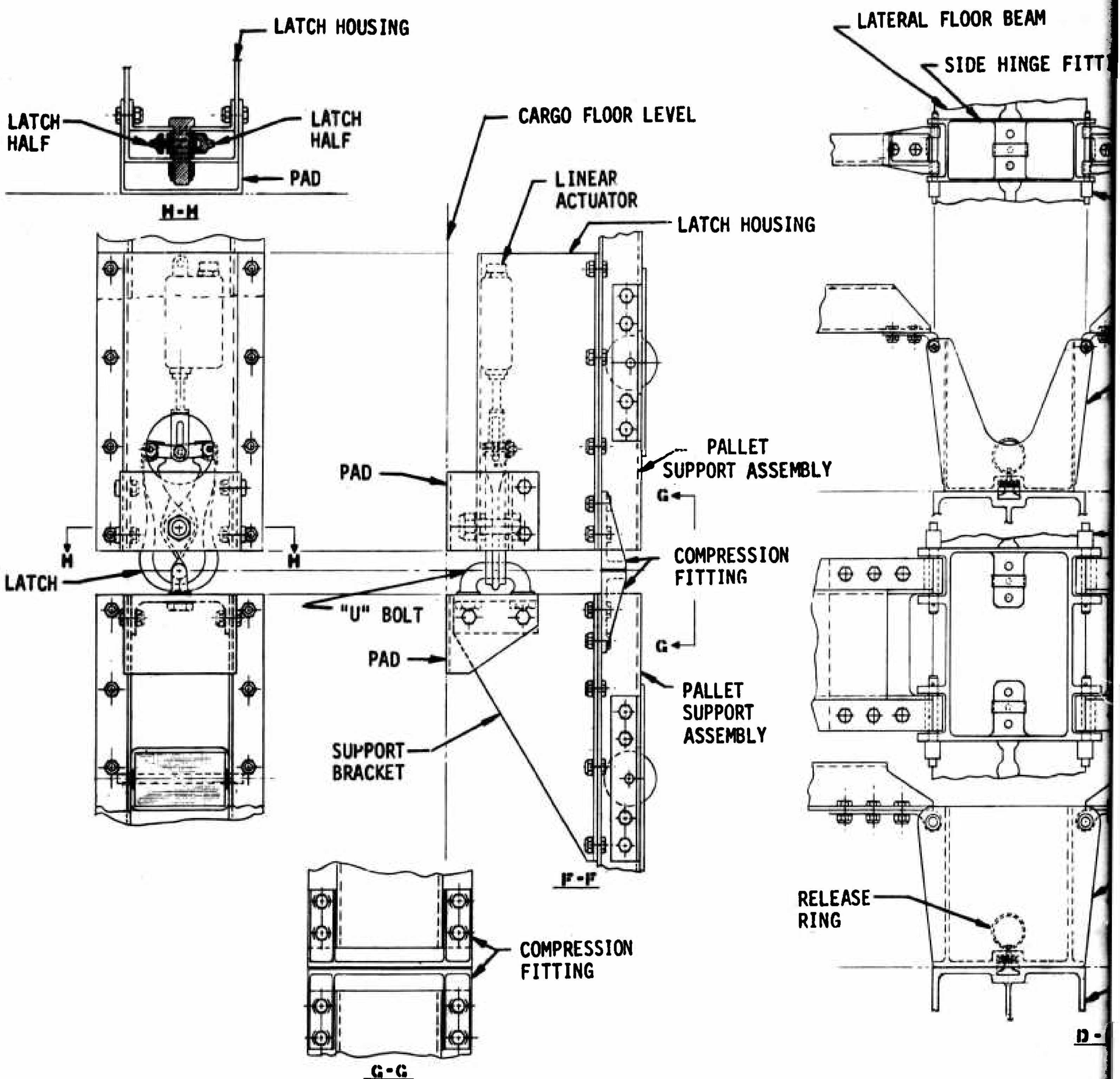
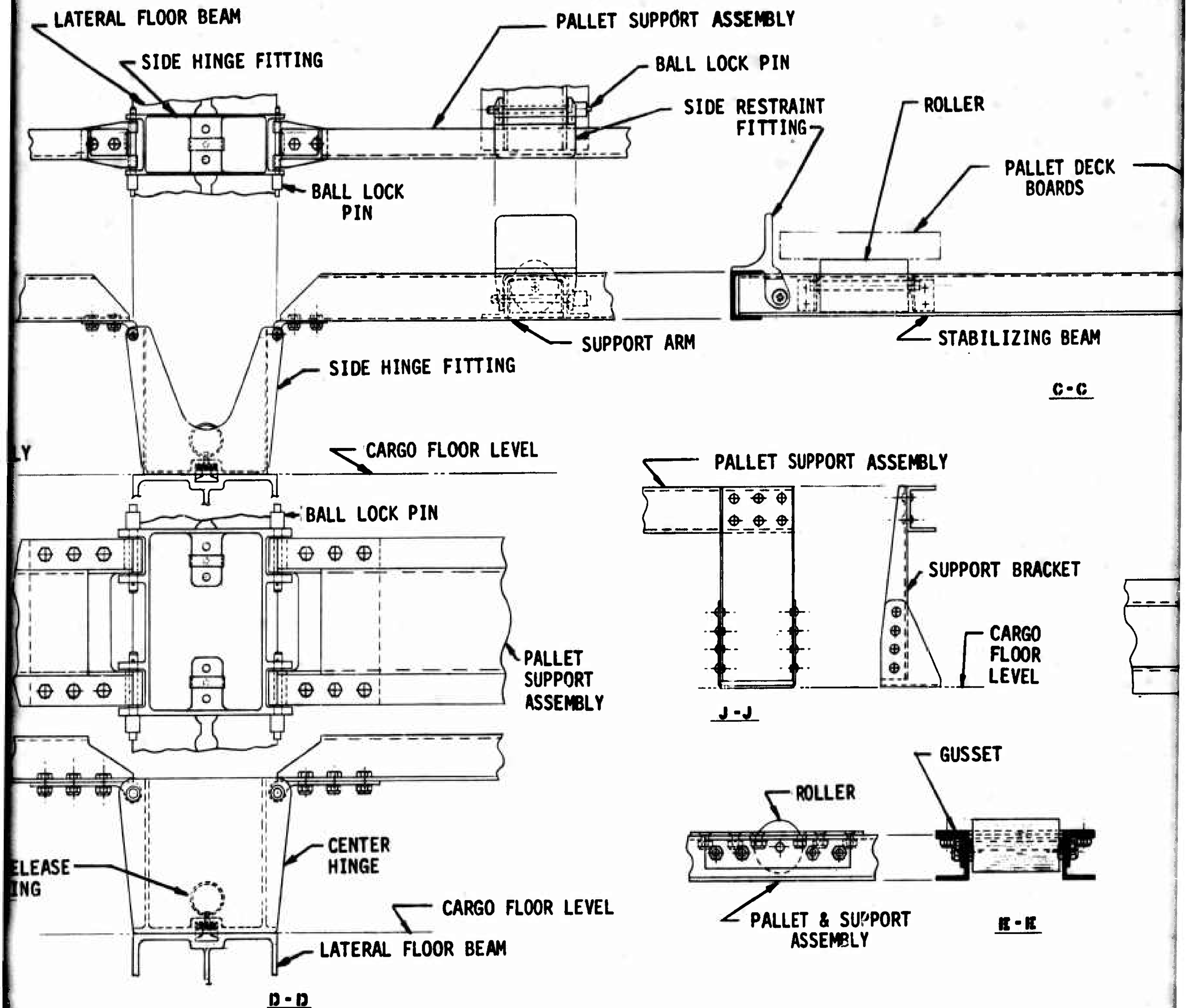
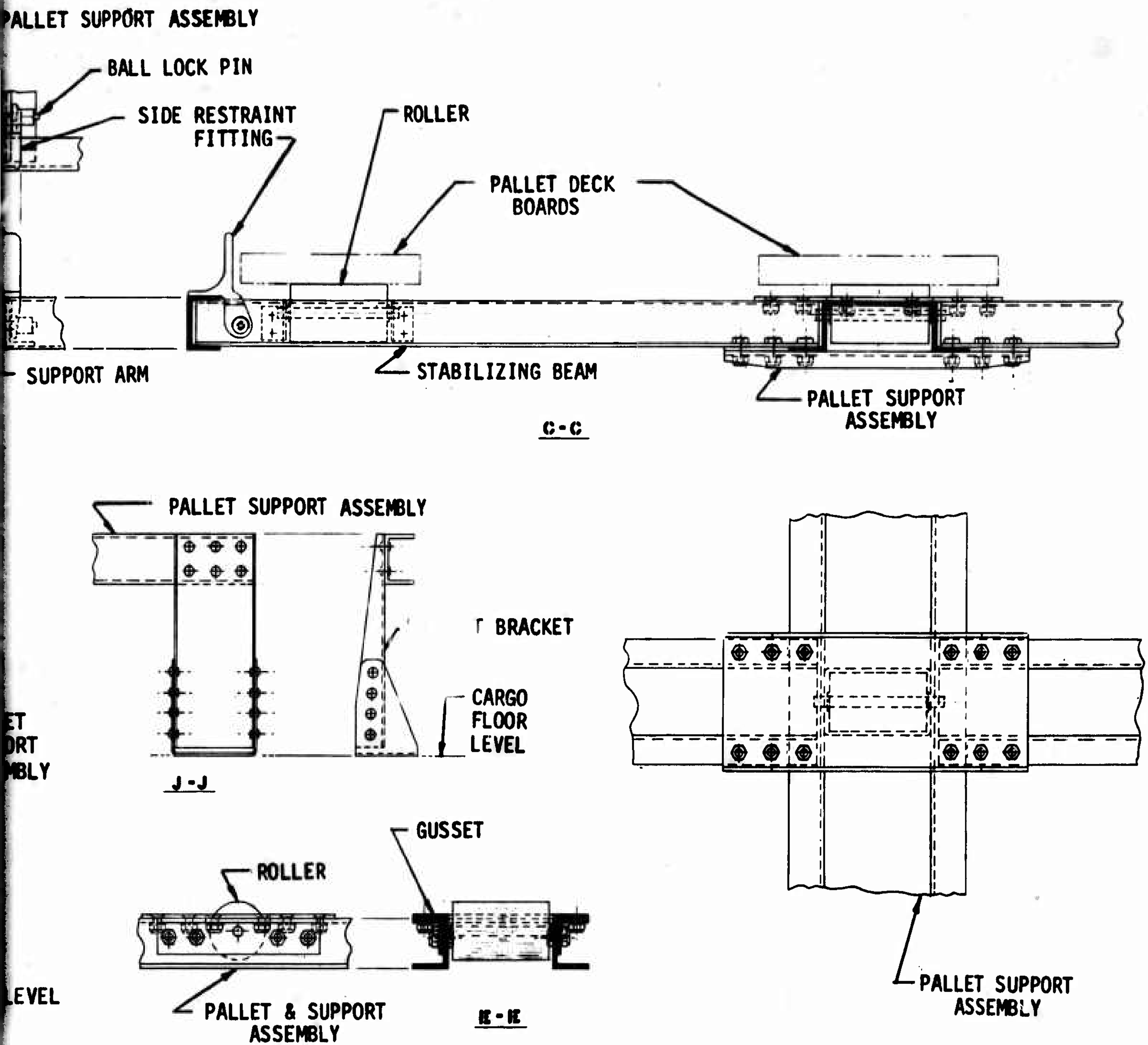


Figure 18. (U) Detail Design of V/M Cargo Handling System – Add-on Pallet Support Assembly.


LATERAL FLOOR BEAM
SIDE HINGE FITTING
PALLET SUPPORT ASSEMBLY
BALL LOCK PIN
SIDE RESTRAINT FITTING
ROLLER
PALLET DECK BOARDS
BALL LOCK PIN
SUPPORT ARM
STABILIZING BEAM
SIDE HINGE FITTING
C-C
CARGO FLOOR LEVEL
PALLET SUPPORT ASSEMBLY
BALL LOCK PIN
SUPPORT BRACKET
CARGO FLOOR LEVEL
PALLET SUPPORT ASSEMBLY
J-J
GUSSET
ROLLER
CENTER HINGE
ELEASE
ING
CARGO FLOOR LEVEL
PALLET & SUPPORT ASSEMBLY
K-K
LATERAL FLOOR BEAM
D-D

2



PALLET SUPPORT ASSEMBLY
BALL LOCK PIN
SIDE RESTRAINT FITTING
ROLLER
PALLET DECK BOARDS
SUPPORT ARM
STABILIZING BEAM
PALLET SUPPORT ASSEMBLY
C-C
PALLET SUPPORT ASSEMBLY
T BRACKET
CARGO FLOOR LEVEL
ET
ORT
MBLY
J-J
GUSSET
ROLLER
LEVEL
PALLET & SUPPORT ASSEMBLY
K-K
PALLET SUPPORT ASSEMBLY

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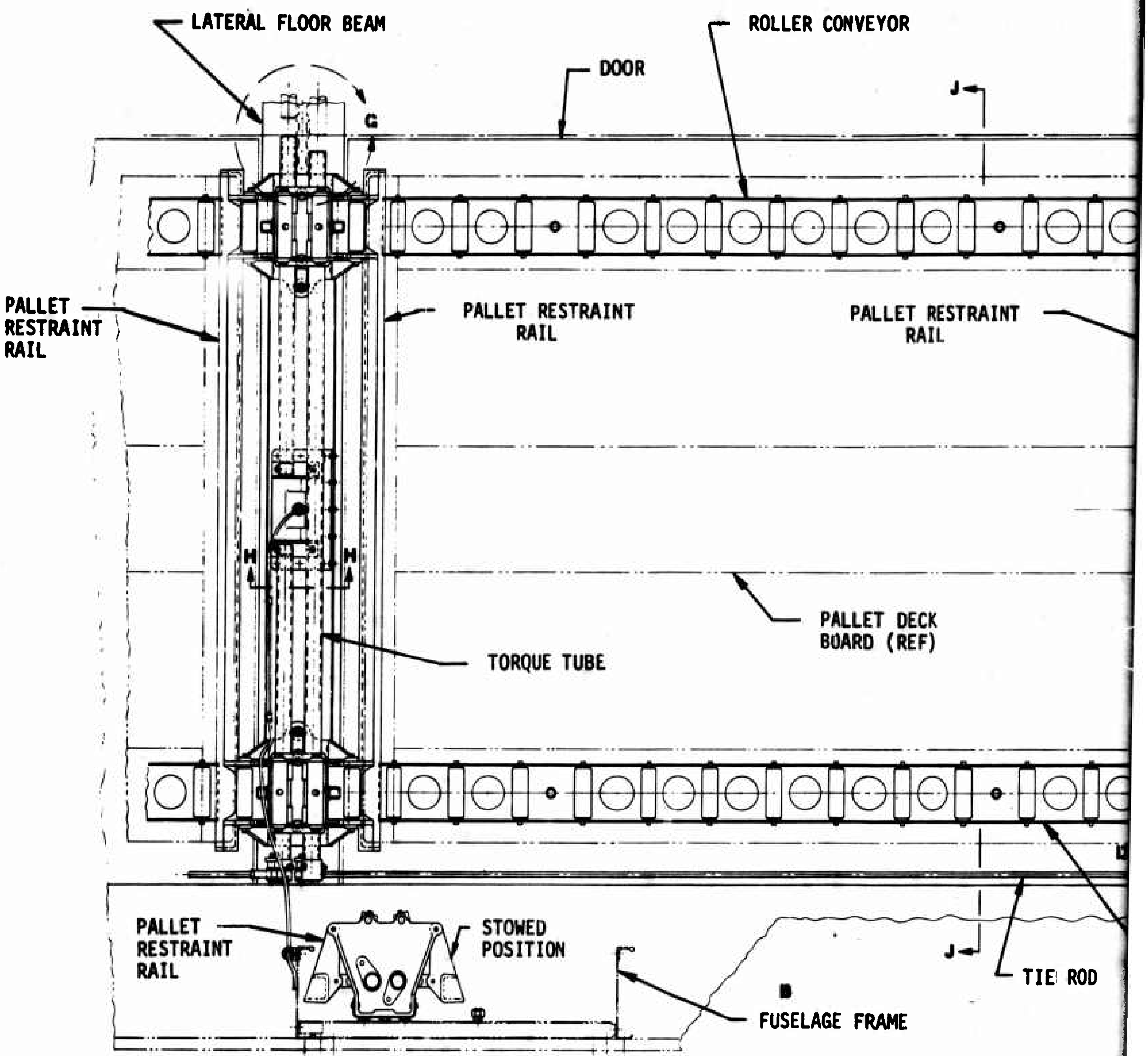
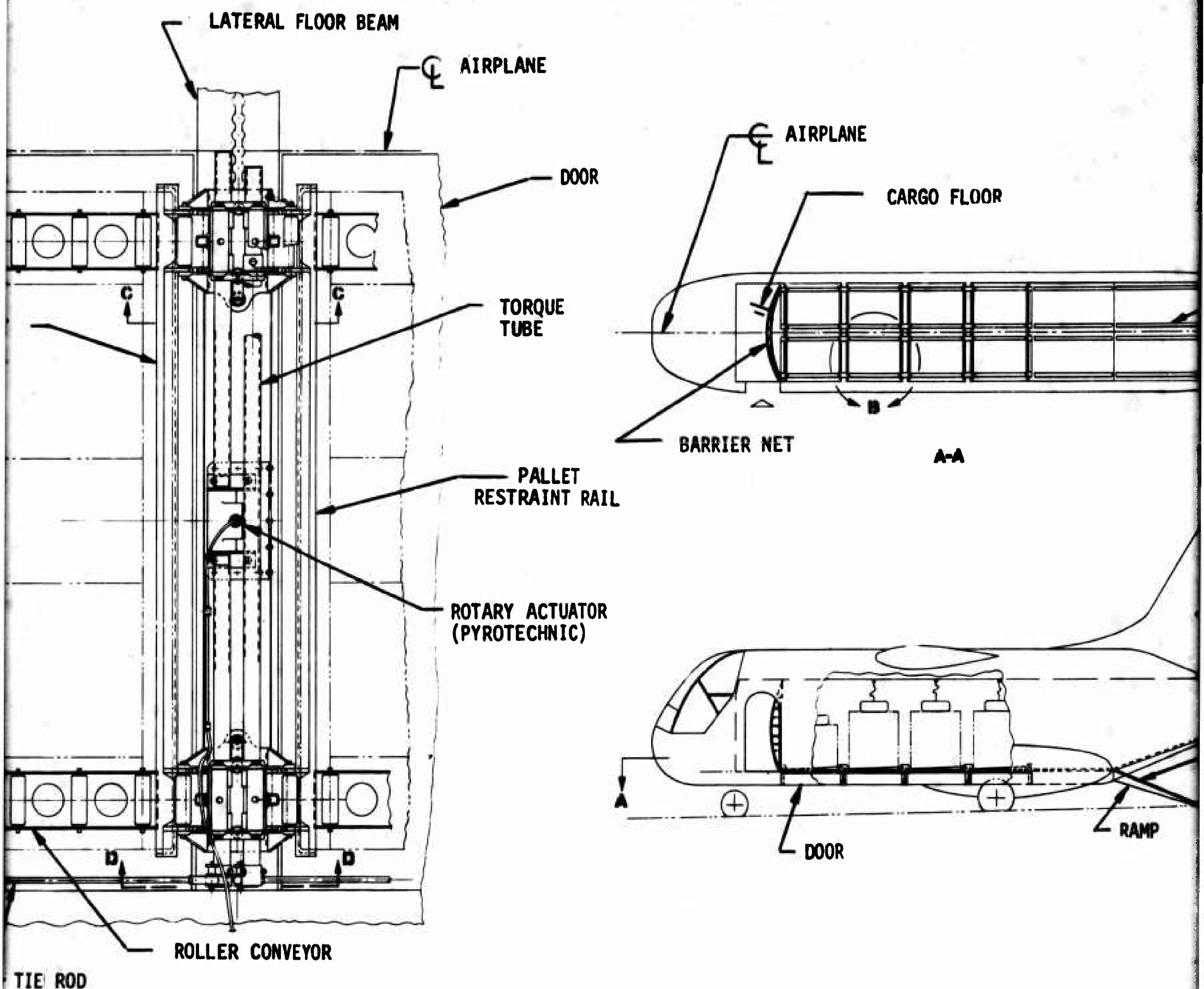
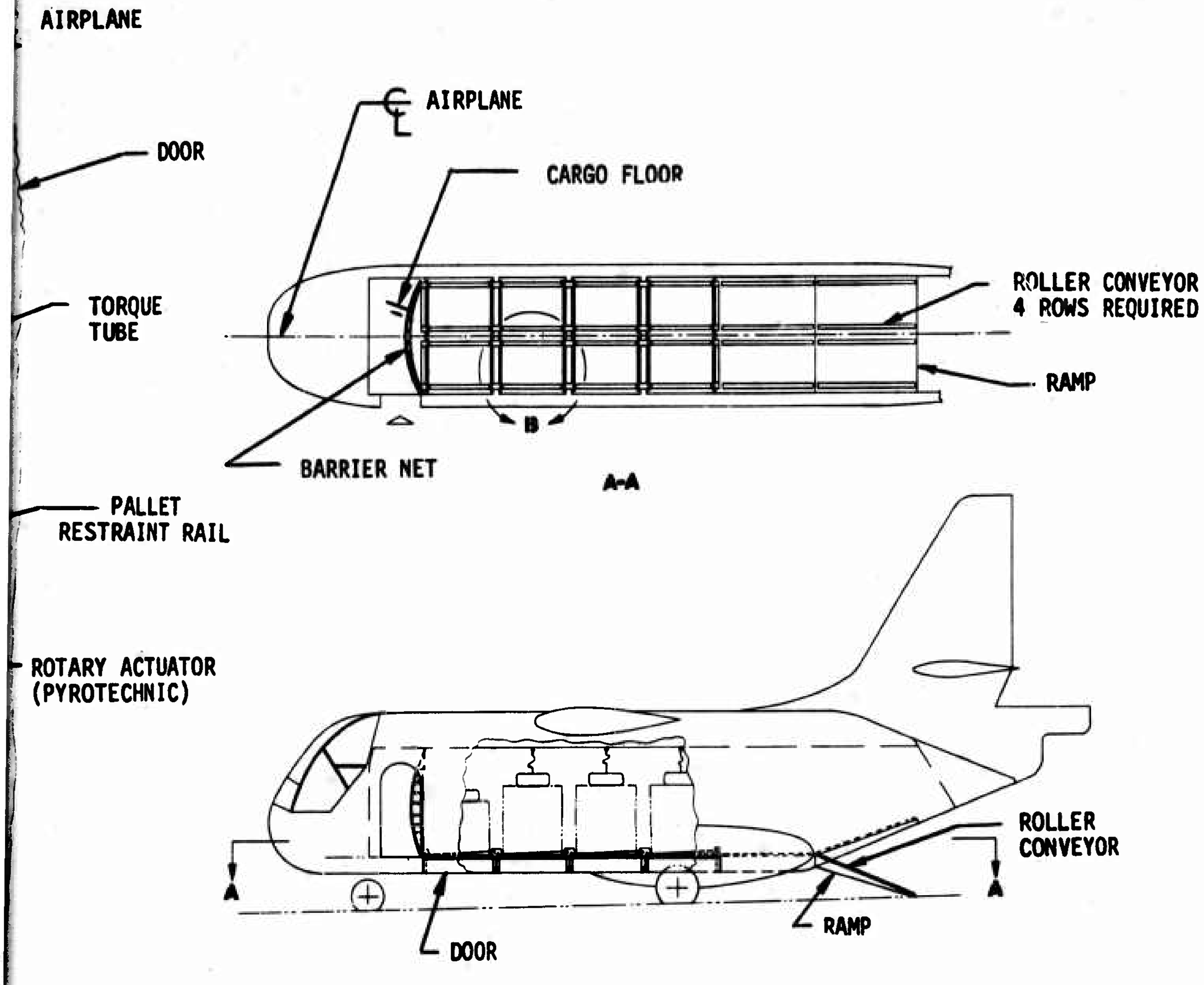


Figure 19. (U) General Arrangement of V/M Cargo Handling System II – Add-on Pallet Restraint Rails.



LATERAL FLOOR BEAM
℄ AIRPLANE
DOOR
TORQUE TUBE
PALLET RESTRAINT RAIL
ROTARY ACTUATOR (PYROTECHNIC)
C
D
ROLLER CONVEYOR
TIE ROD
℄ AIRPLANE
CARGO FLOOR
BARRIER NET
B
A-A
A
DOOR
RAMP

2


AIRPLANE
DOOR
TORQUE TUBE
PALLET RESTRAINT RAIL
ROTARY ACTUATOR (PYROTECHNIC)
℄ AIRPLANE
CARGO FLOOR
ROLLER CONVEYOR 4 ROWS REQUIRED
RAMP
B
BARRIER NET
A-A
ROLLER CONVEYOR
A
A
DOOR
RAMP

3

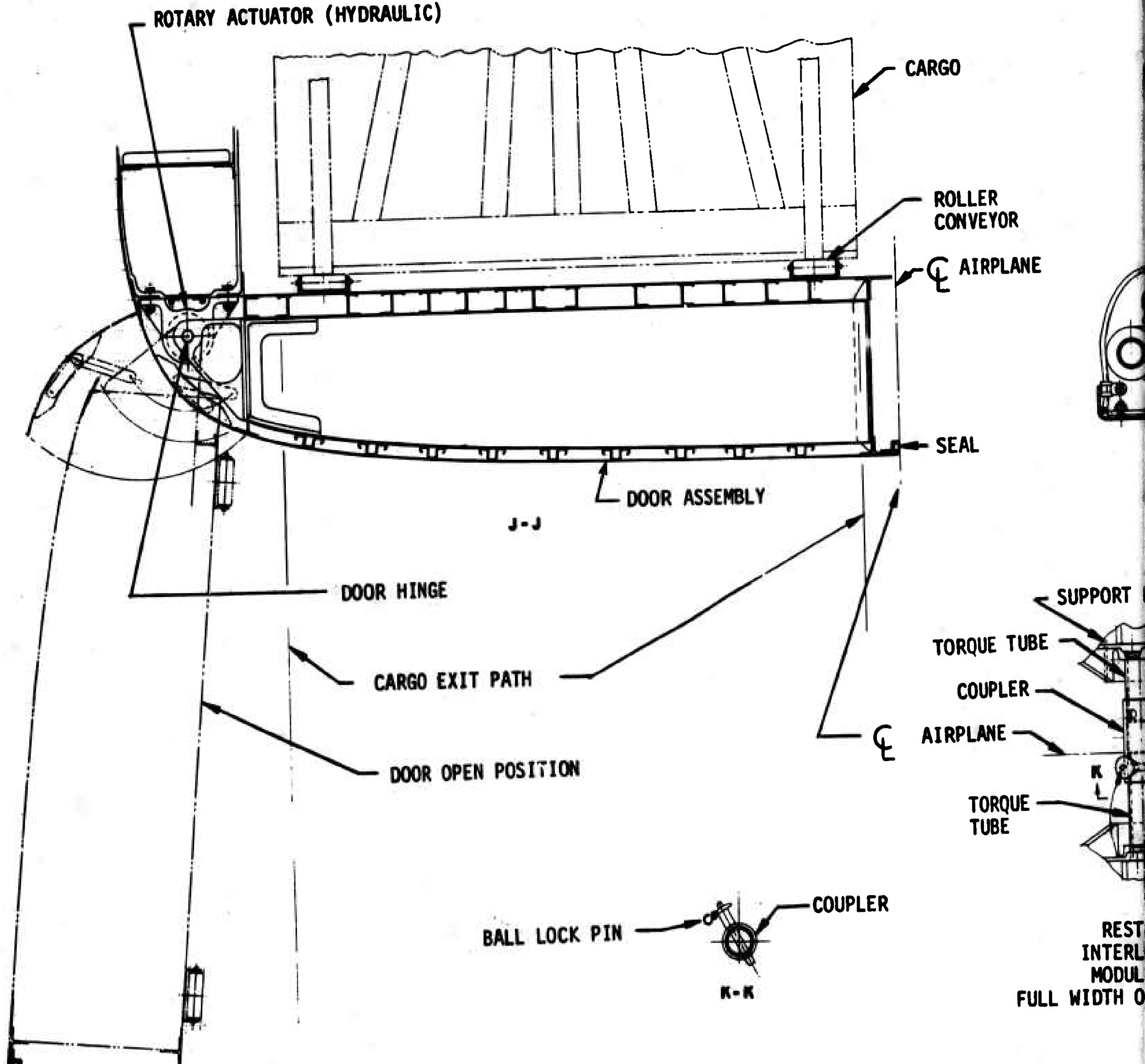
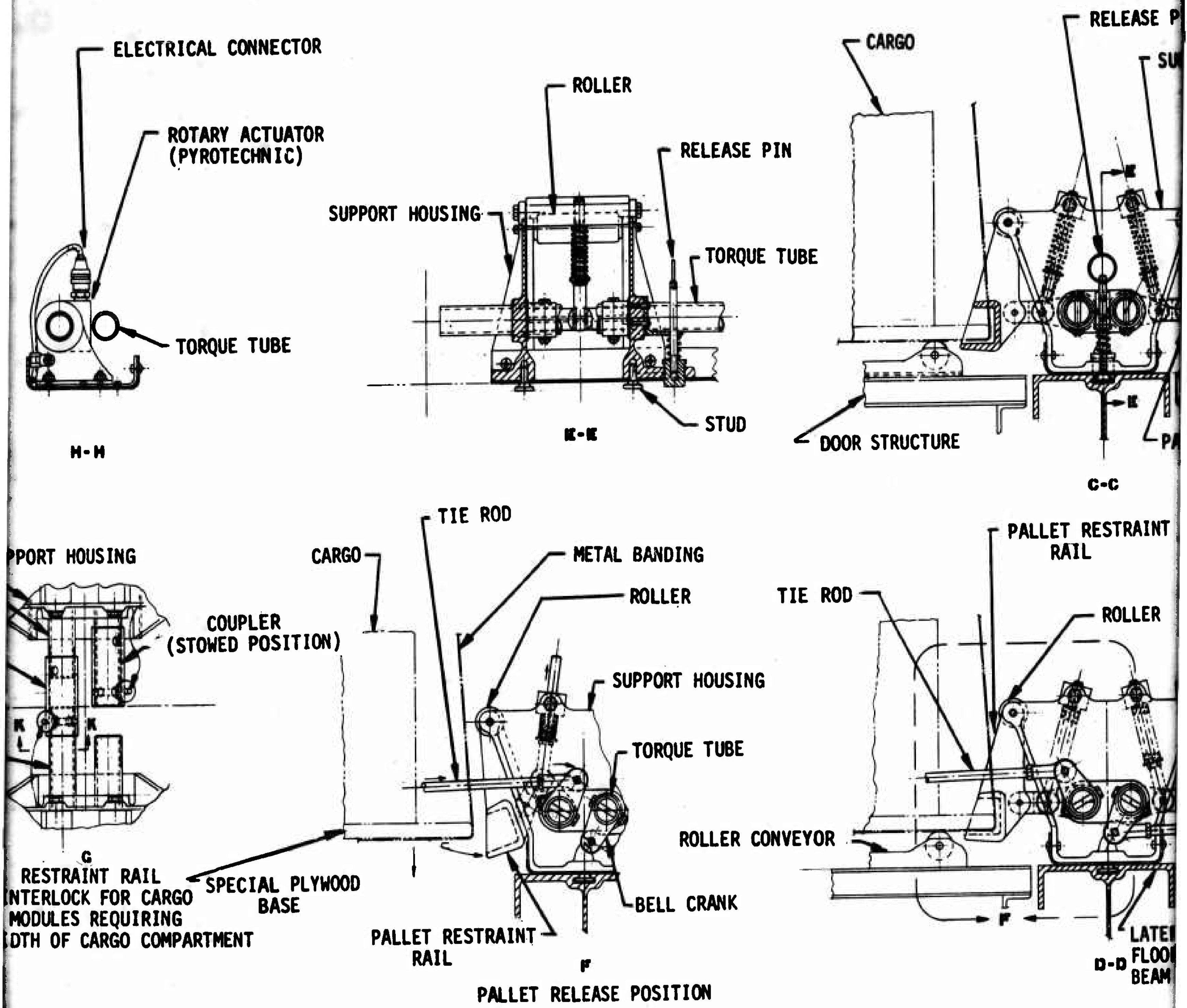
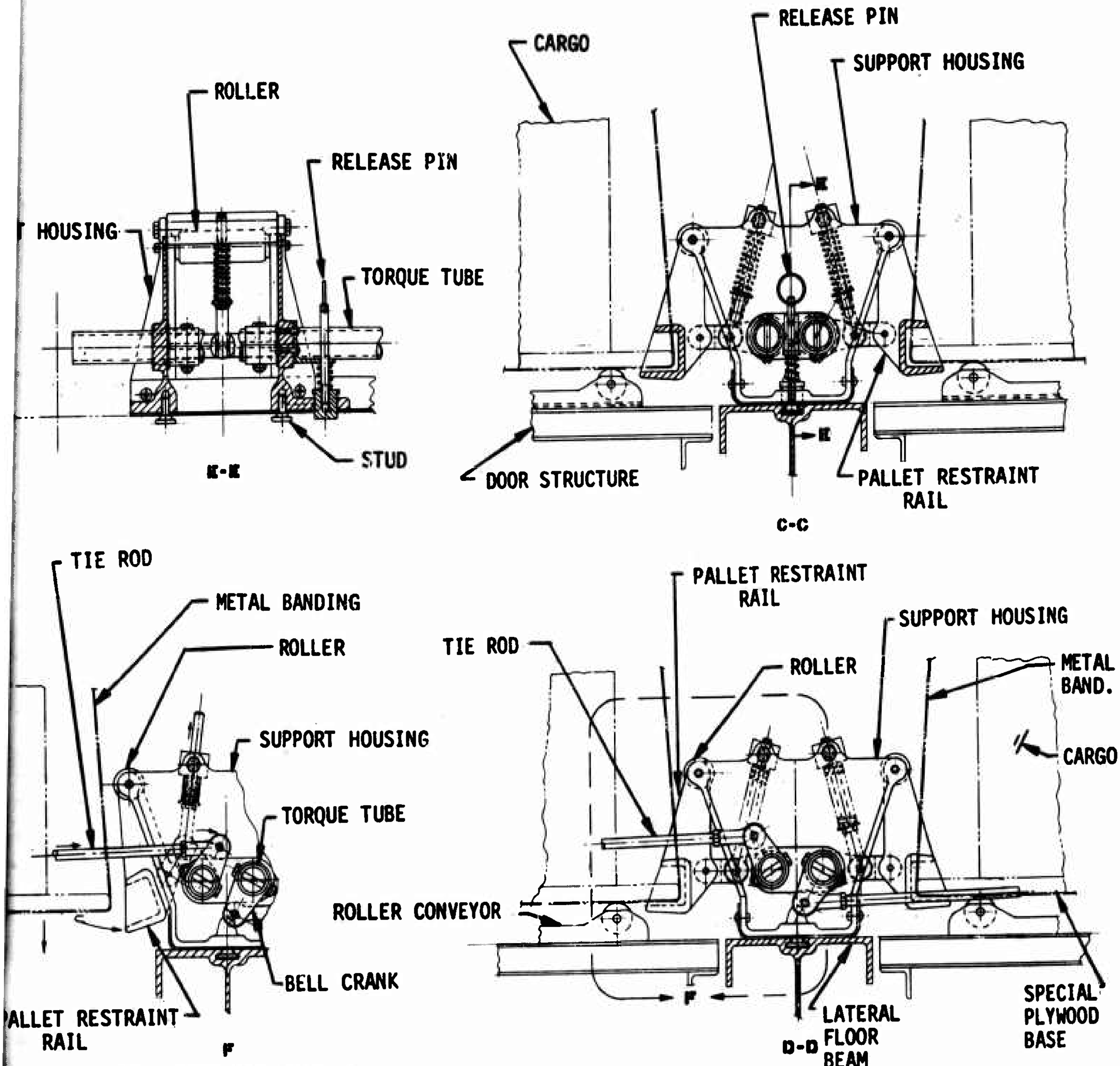


Figure 20. (U) Detail Design of V/M Cargo Handling System II – Add-on Pallet Restraint Rails.


ELECTRICAL CONNECTOR
ROTARY ACTUATOR (PYROTECHNIC)
TORQUE TUBE
H-H
ROLLER
RELEASE PIN
SUPPORT HOUSING
TORQUE TUBE
STUD
K-K
CARGO
RELEASE P
SU
DOOR STRUCTURE
PA
C-C
PPORT HOUSING
K
K
G
RESTRAINT RAIL
INTERLOCK FOR CARGO
MODULES REQUIRING
DTH OF CARGO COMPARTMENT
CARGO
COUPLER (STOWED POSITION)
SPECIAL PLYWOOD BASE
TIE ROD
METAL BANDING
ROLLER
SUPPORT HOUSING
TORQUE TUBE
BELL CRANK
PALLET RESTRAINT RAIL
F
PALLET RELEASE POSITION
PALLET RESTRAINT RAIL
TIE ROD
ROLLER
ROLLER CONVEYOR
F
F
D-D
LATE
FLOO
BEAM

2



PALLET RELEASE POSITION

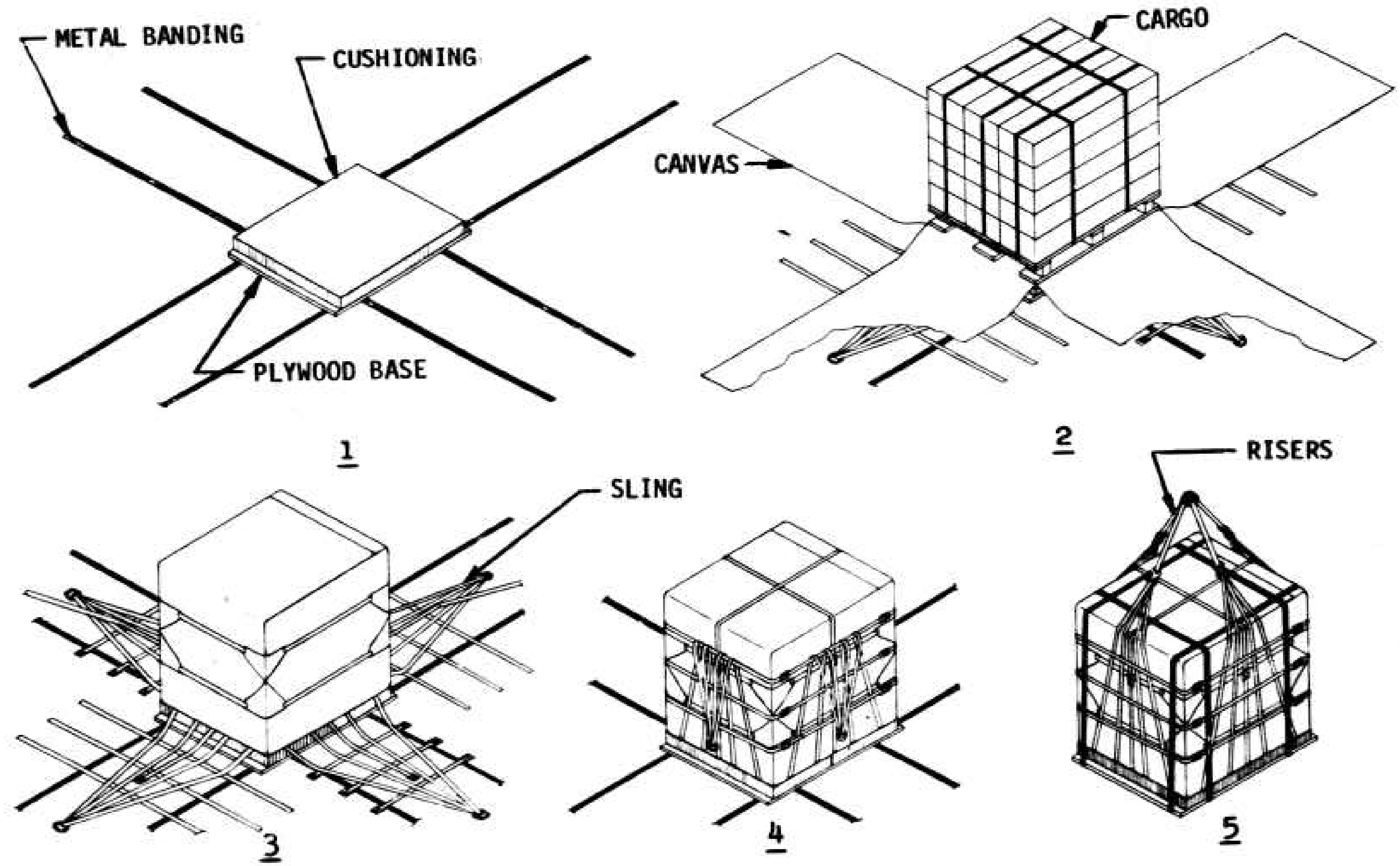


Figure 21. (U) A-22 Airdrop Container Buildup Sequence.

Four rows of roller conveyors are placed on the ramp and cargo floor for movement of palletized cargo. The conveyors are fastened with quick-disconnect attachments and are located to permit conveyance of two MIL-P-15011C wooden pallets positioned side by side.

A cargo barrier net has also been provided with this system to protect the aircraft crew from injury if cargo breaks loose from its normal restraint during a crash condition when normal load factors are exceeded.

System III Description

System III is illustrated in Figures 22, 23 and 24.

The mechanical function of this system is similar to that of System I. The principal difference between these two systems is that System III is integral with the aircraft.

Selection of Optimum System Design

All three vertical/modular cargo handling systems have been evaluated in comparative form in Table VI.

A weight comparison of the three systems is shown in Table VII.

The difference between the delta weights of the three systems is insignificant when compared with the operational flexibility of System III. Thus, System III was selected as the vertical/modular cargo handling system for comparison with the conventional rear cargo extraction system.

The first and most important advantage of System III is that the aircraft does not have to be reconfigured for different cargo missions. This capability is particularly advantageous when delivering air-land palletized cargo to a forward area and returning with personnel or retrograde cargo.

The second advantage is that System III does not require special preparation of palletized cargo for air-land delivery. The system will accommodate cargo loaded and banded on 40 x 48 MIL-P-15011C wooden pallets without additional preparation.

The third advantage of System III is that a minimum of space is needed within the aircraft for stowage of the removable components. Because Systems I and II are removed in their entirety, the volume of stowage space would be much greater than with System III.

Repetitive removal and installation of Systems I and II could cause wear and damage to the components. Frequent installation of either of these two add-on systems would increase the probability that they could be installed improperly.

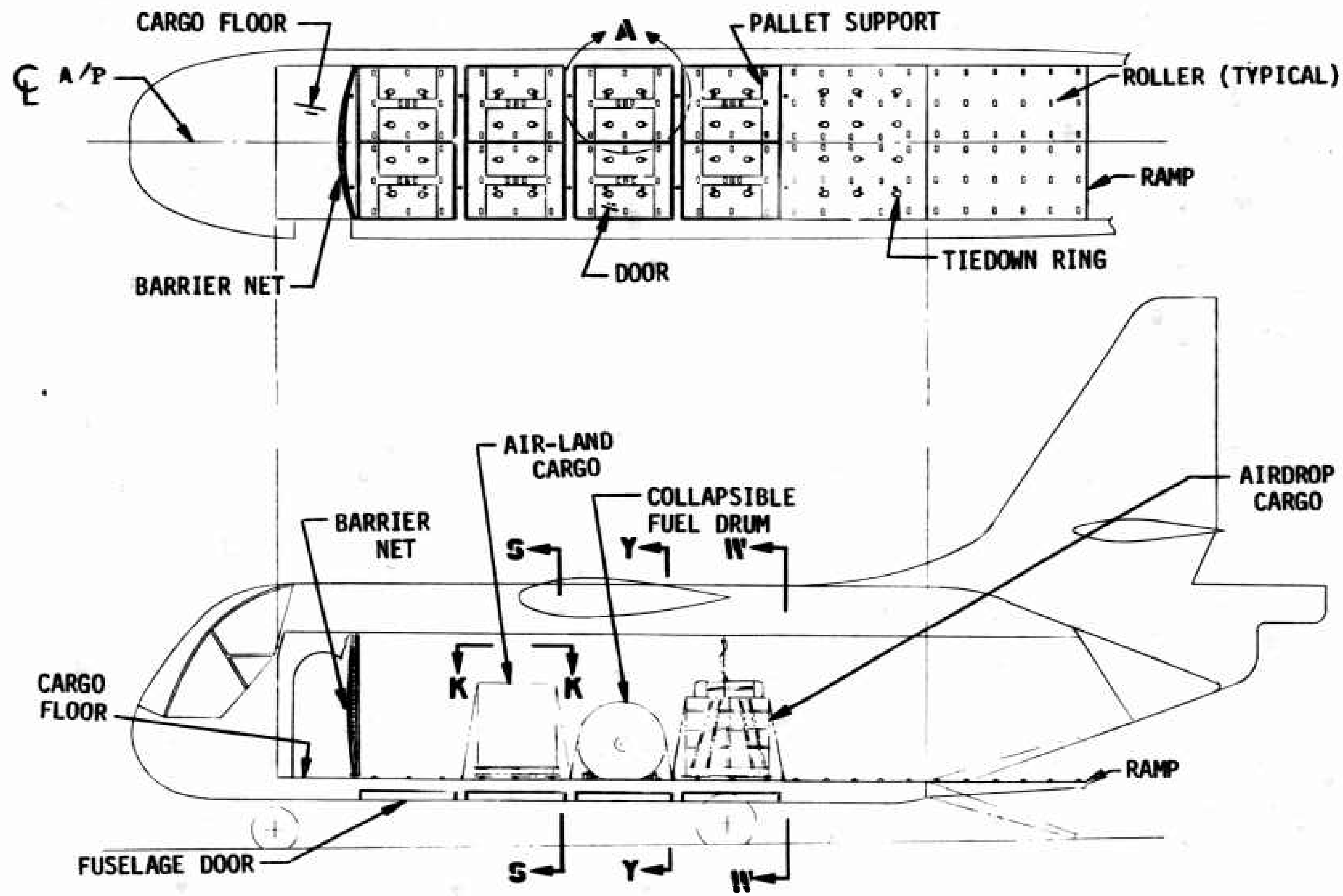


Figure 22. (U) General Arrangement of V/M Cargo Handling System III – Integrated "T" Bar Pallet Support.

DESCRIPTION OF SELECTED DESIGN

Support and Release of Cargo for Airdrop/Hover-Drop

The support and release of cargo modules for airdrop or hover-drop is accomplished by eight pairs of "T" shaped support assemblies. The support assemblies are individually hinged on the lateral floor beams (see Figure 24) and are seated into troughs in the eight bottom doors to provide a flush floor surface. They are constructed of aluminum extrusion and sheet stock and are designed to withstand 300-psf floor loads when seated in the doors.

One pair of "T" bar support assemblies is located over each door and will support and release either 40 x 48 or 43 x 52 cargo pallets. They are connected together with an electromechanical actuated tension latch which is enclosed in a housing attached to one of the support assemblies, and is coupled to a "U" bolt mounted on the other support assembly (see Figure 24).

The latch assembly has a spring-actuated, over-center mechanism, which is driven by an electrical linear actuator to release or latch together the two support assemblies. The latch is designed to support the cargo module after the bottom doors have been opened for an airdrop. The inter-reaction between a compression fitting mounted to the support assemblies above the tension latch will eliminate longitudinal bending in the lateral floor beams on which each support assembly is hinged.

The support assemblies rotate freely about their hinge lines when they are released by the latch assembly to airdrop cargo. A damping device is installed on the lateral floor beams to absorb the kinetic energy of the support assemblies as they swing open.

Electrical rotary actuators mounted on the web of the lateral floor beams are used to lift the individual support assemblies up to the latched position after the cargo has been dropped, prior to closing the belly doors (see Figure 24).

Cargo modules exceeding a lateral length of 43 inches and less than 84 inches will be supported and released for airdrop by two pairs of support assemblies (4 "T" bar supports).

Cargo Conveyance

Six rows of rollers are integrated into the ramp, cargo floor, doors, and support assembly. The rows are located to contact the six bottom deck boards of two 40 x 48 MIL-P-15011C pallets positioned side by side.

The rollers are permanently installed and project 1/2 inch above the cargo floor level (see Figure 23). The 1/2-inch roller protrusion was selected as the optimum projection to convey all palletized cargo and yet minimize

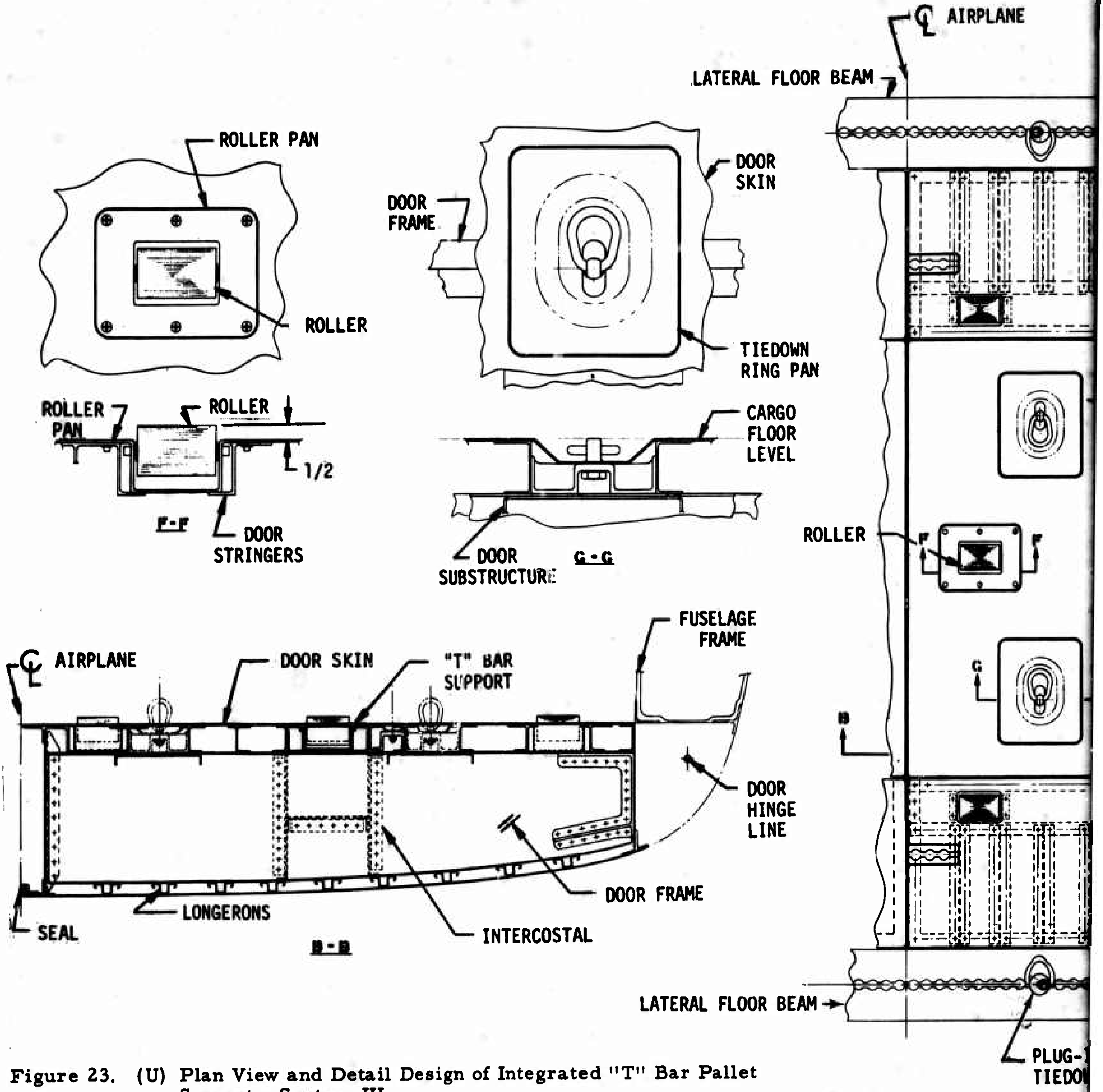
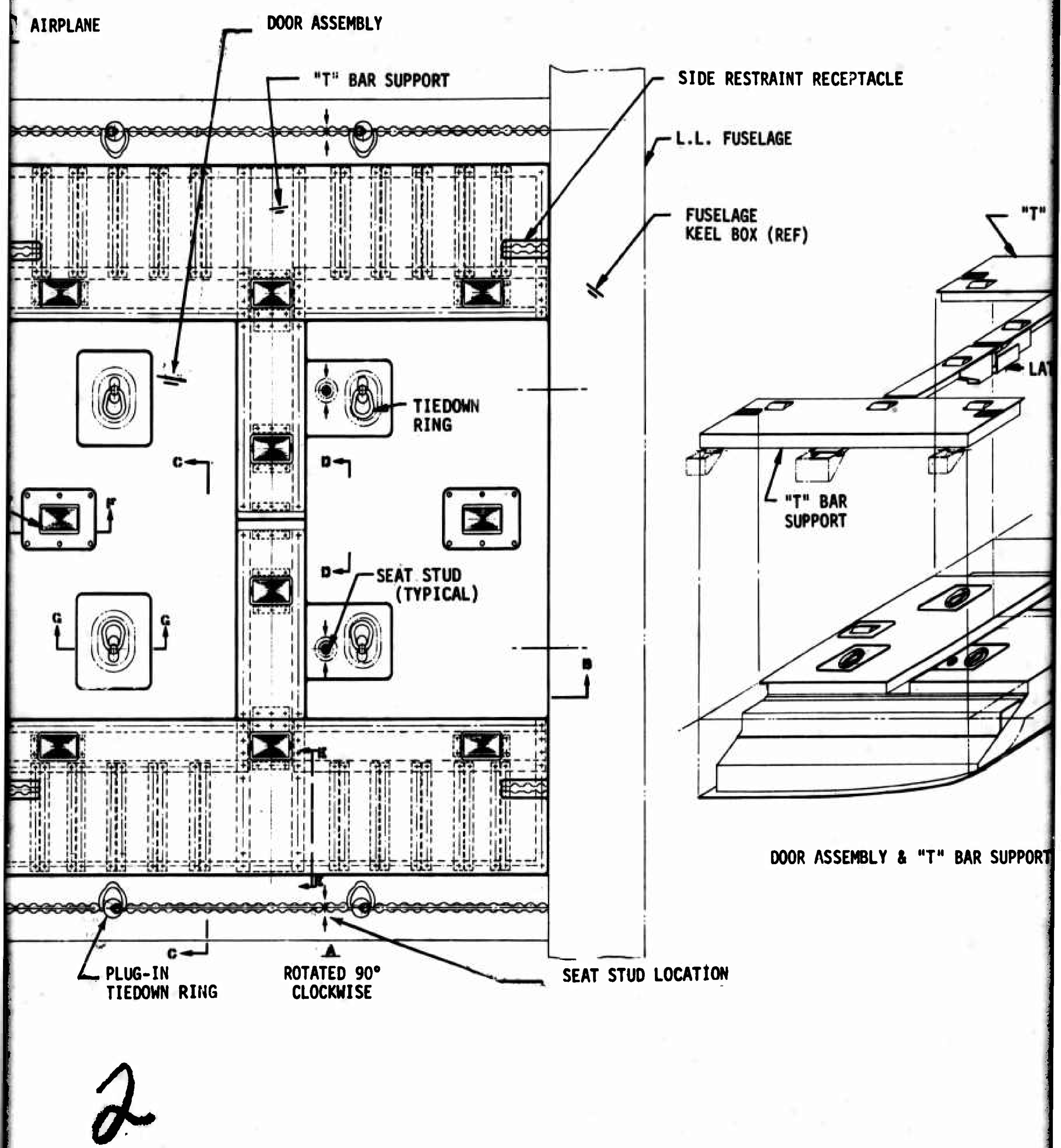
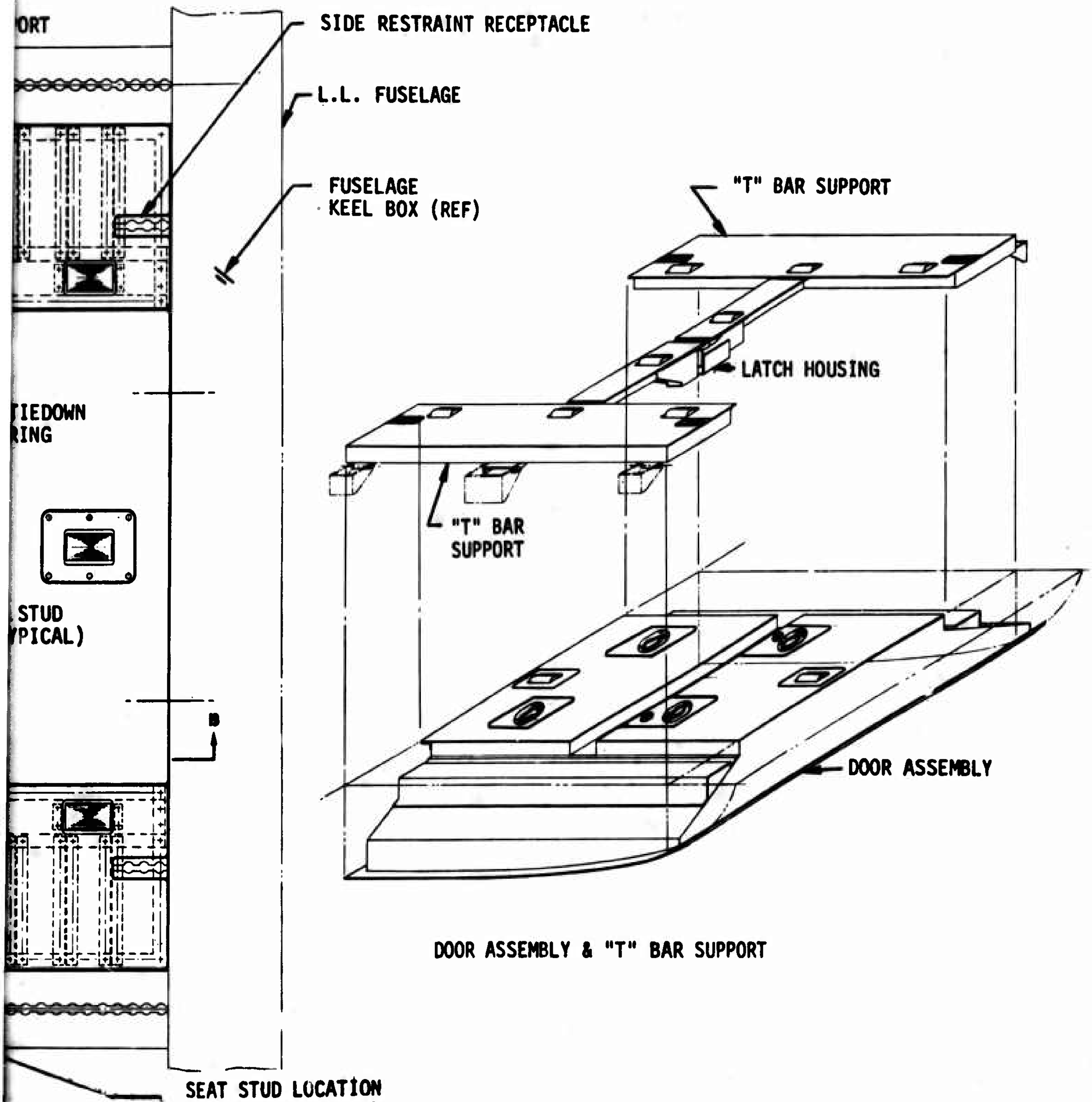


Figure 23. (U) Plan View and Detail Design of Integrated "T" Bar Pallet Support – System III.



AIRPLANE
DOOR ASSEMBLY
"T" BAR SUPPORT
SIDE RESTRAINT RECEPTACLE
L.L. FUSELAGE
FUSELAGE KEEL BOX (REF)
"T"
TIEDOWN RING
C
D
F
"T" BAR SUPPORT
SEAT STUD (TYPICAL)
G
G
B
K
DOOR ASSEMBLY & "T" BAR SUPPORT
C
A
PLUG-IN TIEDOWN RING
ROTATED 90° CLOCKWISE
SEAT STUD LOCATION
2



DOOR ASSEMBLY & "T" BAR SUPPORT

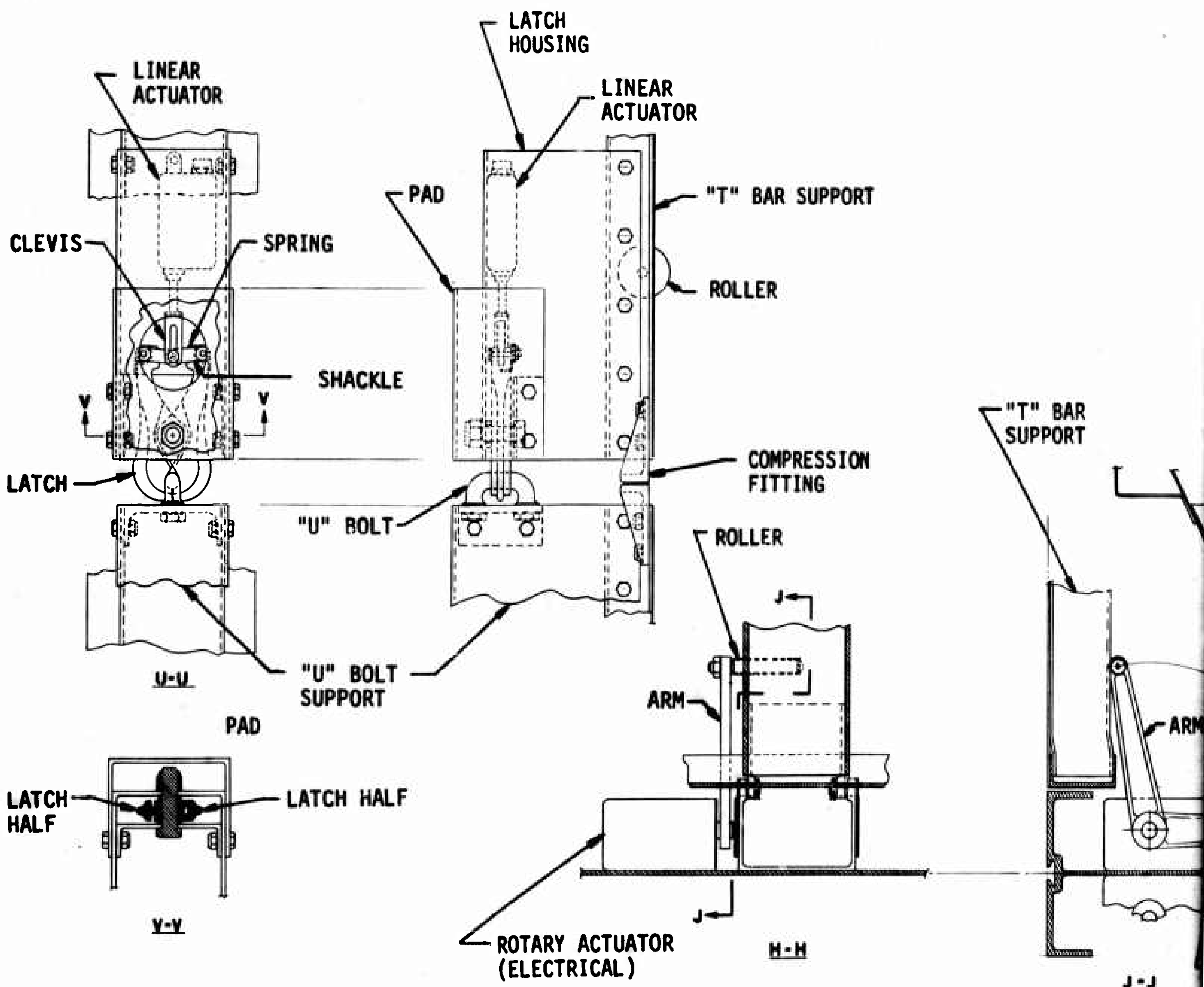
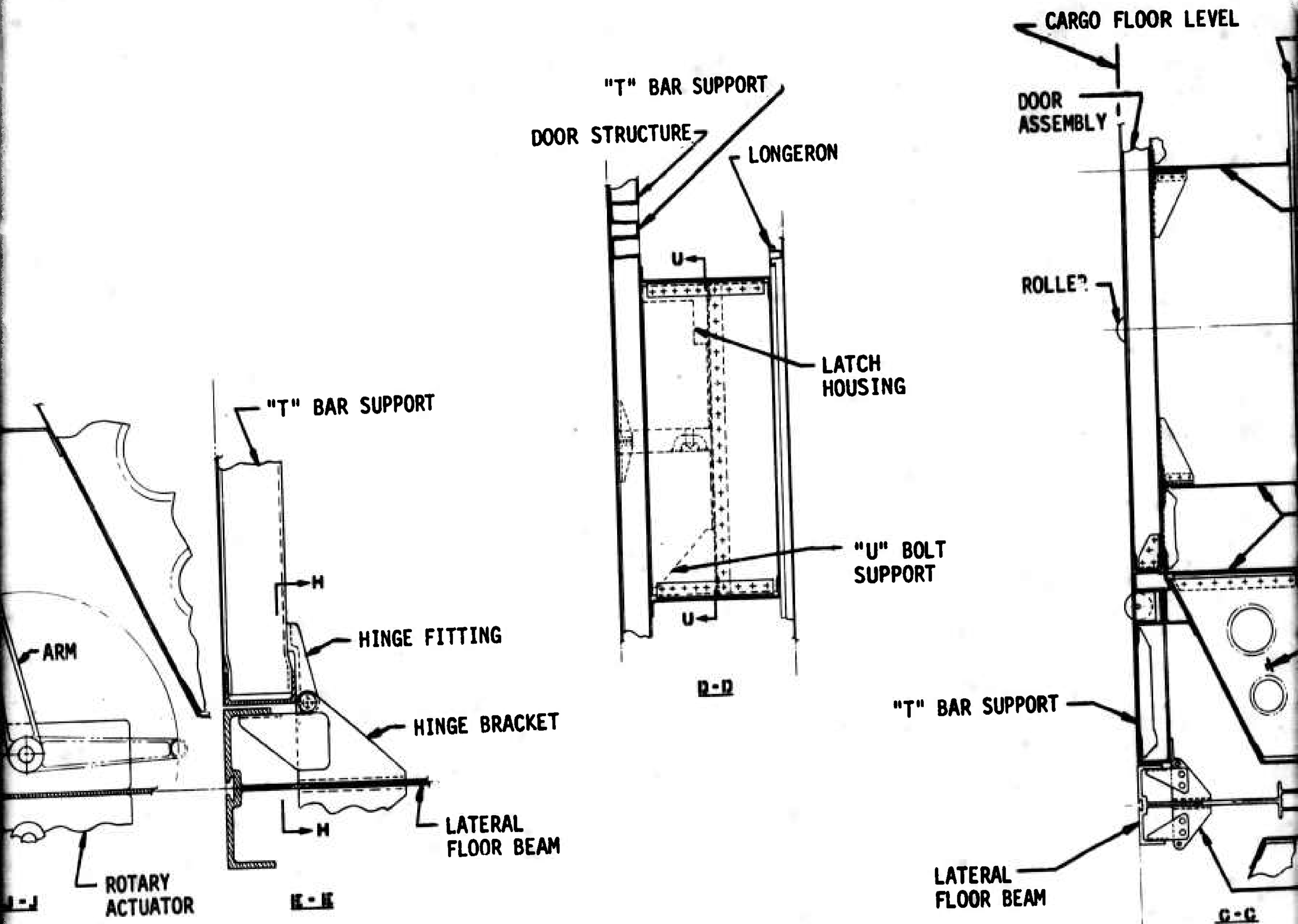
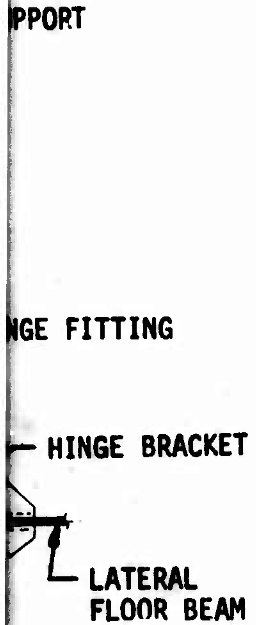
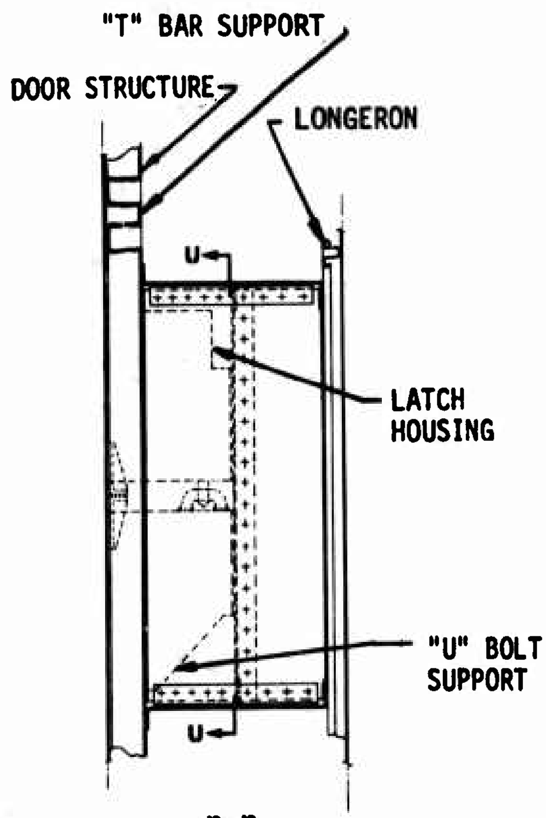


Figure 24. (U) Detail Design of V/M Cargo Handling System III.

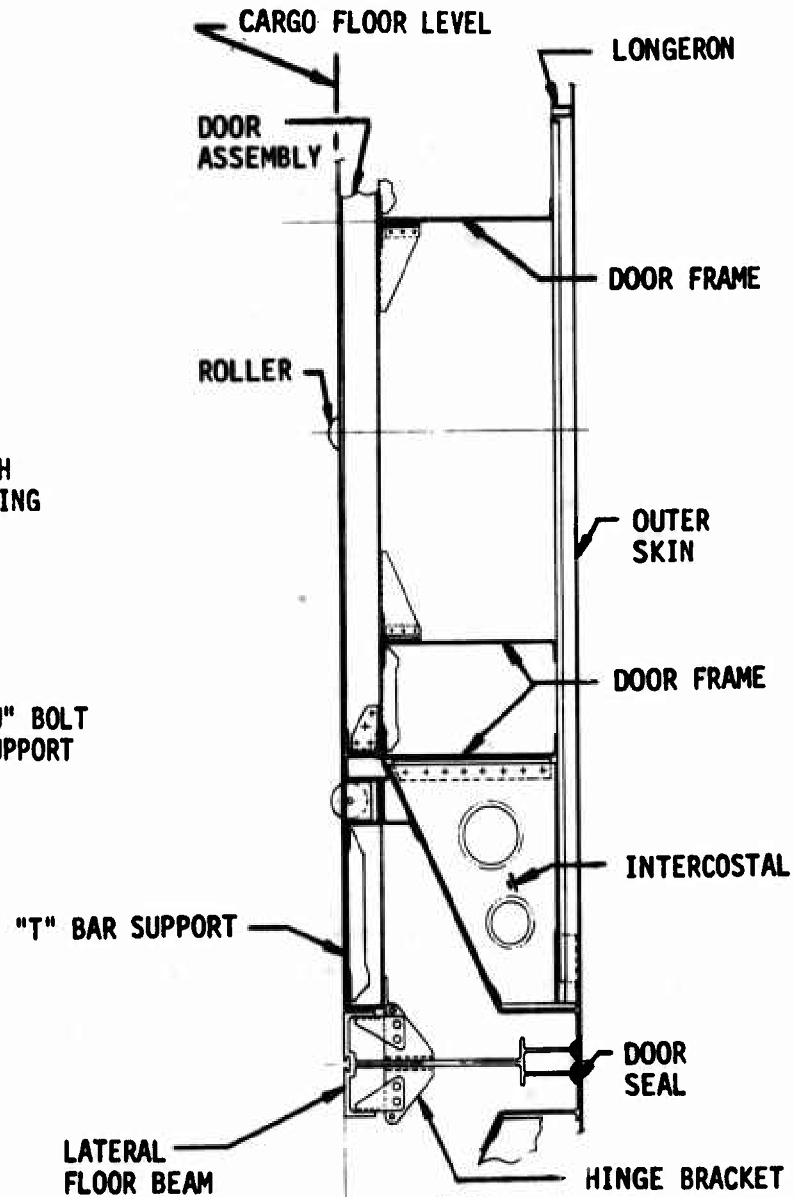

CARGO FLOOR LEVEL
"T" BAR SUPPORT
DOOR STRUCTURE
LONGERON
DOOR ASSEMBLY
ROLLER
LATCH HOUSING
"U" BOLT SUPPORT
D-D
"T" BAR SUPPORT
ARM
HINGE FITTING
HINGE BRACKET
LATERAL FLOOR BEAM
ROTARY ACTUATOR
"T" BAR SUPPORT
LATERAL FLOOR BEAM

2


PPORT
NGE FITTING
HINGE BRACKET
LATERAL
FLOOR BEAM


"T" BAR SUPPORT
DOOR STRUCTURE
LONGERON
U
LATCH
HOUSING
"U" BOLT
SUPPORT
U

D-D


CARGO FLOOR LEVEL
LONGERON
DOOR
ASSEMBLY
DOOR FRAME
ROLLER
OUTER
SKIN
DOOR FRAME
INTERCOSTAL
"T" BAR SUPPORT
DOOR
SEAL
LATERAL
FLOOR BEAM
HINGE BRACKET

C-C

TABLE VI (U)

DESCRIPTION AND COMPARISON OF VERTICAL/MODULAR CARGO HANDLING SYSTEMS CONSIDERED

Function	System I Add-on Pallet Support Assembly	System II Add-on Pallet Restraint Rail	Inte
Cargo conveyance for loading & unloading.	Six rows of roller conveyors placed on top of cargo floor and ramp.	Four rows of roller conveyors placed on top of cargo floor and ramp.	Six ram sup
Cargo support.	Two "T" bar supports positioned over each bottom fuselage door and attached to the top of lateral floor beams; "T" bar supports connected to an electromechanical latch.	Pallet restraint rails support forward and aft edges of plywood pallet base.	"T" ces doo flo
Cargo restraint.	Tiedown straps for up load and mechanical restraint fittings for side, forward, and aft flight loads; barrier net for forward 8g crash load.	Pallet restraint rails restrain cargo in all directions for flight loads; 8g forward crash load accommodated by barrier net at forward end of cargo compartment.	Tie me sid loa cra
Cargo release mechanism.	Single point; electromechanical latch connecting "T" bar supports.	Pallet restraint rails linked together with a tie rod and actuated by a pyrotechnic rotary actuator.	Sin lat sup
Special preparation of palletized air-land cargo.	None required.	One-half inch plywood base banded to cargo module; see appendix.	No
Reconfiguration of cargo floor for different cargo missions.	Removal of system required for transport of vehicles and/or troops; system would be stowed within aircraft.	Removal of system required for transport of vehicles and/or troops; system would be stowed within aircraft.	No mo co

R

System II allet Restraint Rail	System III Integrated "T" Bar Pallet Support	Rating
s of roller conveyors placed cargo floor and ramp.	Six rows of rollers recessed into ramp, cargo floor, and pallet support assemblies.	All systems equal for conveying cargo; Systems I and II require stowage provisions for alternate missions.
straint rails support nd aft edges of plywood e.	"T" bar supports seated into recesses in the bottom fuselage doors and hinged on the lateral floor beams.	All systems equal for supporting modules over openings; Systems I & II supports require stowage provision for alternate missions.
straint rails restrain cargo ctions for flight loads; d crash load accommo- barrier net at forward end compartment.	Tiedown straps for up load and mechanical restraint fittings for side, forward, and aft flight loads; barrier net for forward 8g crash load.	Systems I & II are equal; System II utilizes special pallet to eliminate need for tiedown straps.
straint rails linked together rod and actuated by a ic rotary actuator.	Single point; electromechanical latch connecting "T" bar supports.	Systems I & III are superior because the load is released by a single point actuated mechanism; System II releases load by a single point actuation requiring busing between two release mechanisms.
nch plywood base banded to dule; see appendix.	None required.	Systems I & III are superior.
of system required for of vehicles and/or troops; ould be stowed within	Not required; system will accommodate any cargo mission without conversion.	System III is superior.

2

TABLE VII (U)

WEIGHT COMPARISON OF V/M CARGO HANDLING SYSTEMS

Item		Basic Struct. Config.	Modified Structure With System I Add-on "T" Bar	Modified Structure With System II Add-on Pallet Restraint Rail	Modified Structure With System III Integrate "T" Bar
Center Section Structural Weight (Table XV) (8 Door Opening Config.)		2396	2464	2464	2464
Door Assemblies (Table XIV)		0	592	592	640
Pallet Support & Release Mechanism		0	319*	202*	328
Roller Conveyor System		0	56*	131*	46
Door Latching & Actuating System (Table XIV)		0	252	252	252
Hydraulic Control System		0	40	40	40
Electrical Control System		0	12	12	12
Airdrop Sequence Control System		0	40*	40*	40*
Barrier Net Fittings, Anchor Lines		0	8	8	8
Barrier Net & Cargo Straps		0	41*	41*	41*
Cargo Restraint Fittings		0	28*	0	48*
Total Center Section Weight Plus System		2396	3852	3782	3919
V/M Cargo Handling System Weight Penalty		0	1456	1386	1523
Special Preparation of Cargo for Air-land Mission	Plywood Base for Pallet	0	0	184	0
	Banding (Metal Strapping)	0	0	80	0
	Total Weight Penalty Air-land	0	1456	1650	1523
Total Weight Removable*		0	484*	414*	129*

* Indicates items that can be removed from the aircraft

interference with other types of cargo. Bulk cargo, vehicles, troops, and operating personnel may traverse the cargo floor without adverse effect to either the cargo or the rollers.

The rollers installed in the support assembly also act as roller guides during the airdrop of cargo modules by reducing friction if the module contacts the support assembly during exit.

Cargo Restraint

Mechanical restraint fittings are installed on the lateral floor beams to restrain each cargo pallet in a forward and aft direction (see Figure 25).

The fittings are plugged into the top of the floor beam with quick-release fasteners. Each restraint fitting is adjustable to accommodate 40 x 48 pallets or 43 x 52 A-22 airdrop containers. Rollers engage the forward and aft edges of pallets to restrain the cargo and to reduce the friction during airdrop.

Cargo side restraint fittings plug into receptacles in the support assembly. Two configurations of side restraint fittings are required to provide restraint for either 40 x 48 pallets or 43 x 52 pallets. These two side restraint fittings are illustrated in Figure 25.

Vertical restraint of cargo is accommodated by tiedown straps as shown in Figure 25. When airdropping, the cargo modules fall out from under the tiedown straps, which are retained within the cargo compartment by a bungee cord tied from the top of the straps to the overhead structure (see Figures 26 and 27).

Nonpalletized collapsible fuel drums are restrained as shown in Figure 28. The drums are rolled into the cargo compartment and positioned over the bottom fuselage openings between the lateral floor beams. Tiedown straps are installed over the fuel drum and attached to tiedown rings in the lateral floor beams. The tiedown straps restrain the cargo vertically as well as forward and aft. Wooden chocks, wedged between the drum and the floor of the cargo compartment, assist forward and aft restraint.

The combination of the restraint fittings and tiedown straps will secure the modules individually for all normal flight loads. The restraining of cargo modules for a forward crash load factor of 8g will be accomplished by a single barrier net constructed of interwoven nylon webbing and attached to fuselage fittings at the forward end of the cargo compartment (see Figure 22). Any cargo which breaks loose from its normal restraint during a crash, will be restrained by the barrier net to prevent injury to crew members. This type of emergency cargo restraint is currently being used in commercial cargo transport aircraft.

The restraint fittings, tiedown straps, and barrier net are stowed within the cargo compartment when not in use.

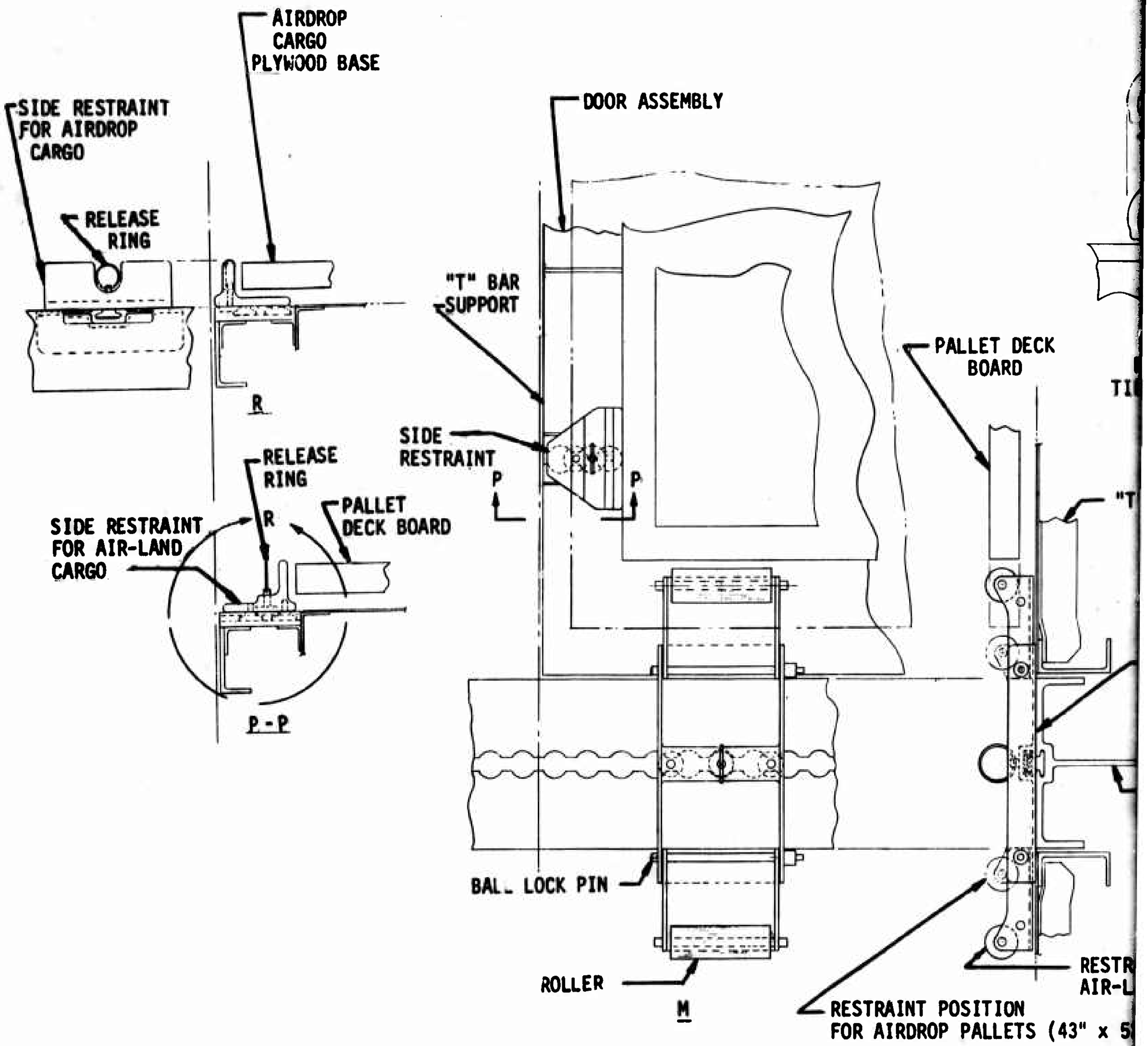
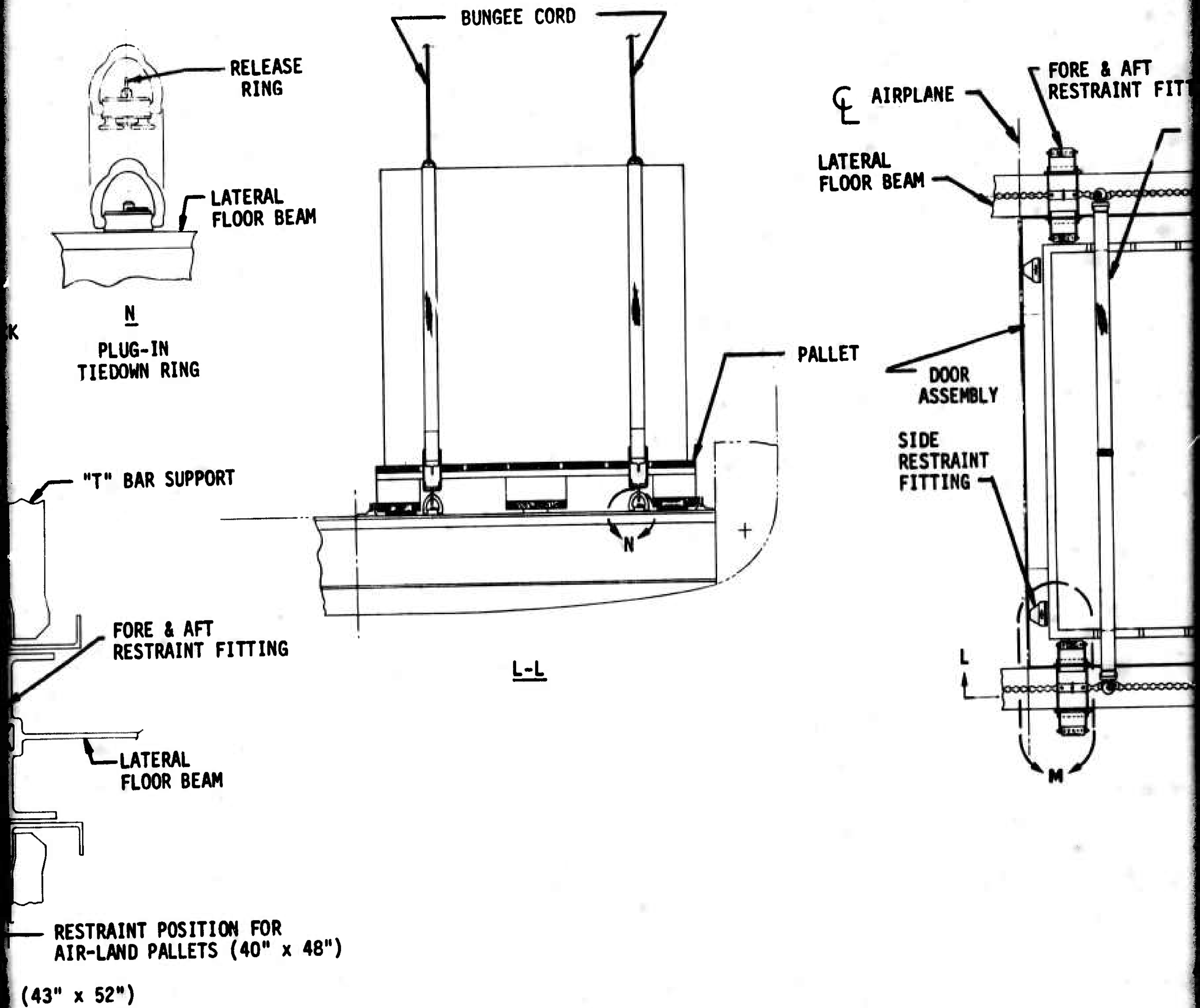
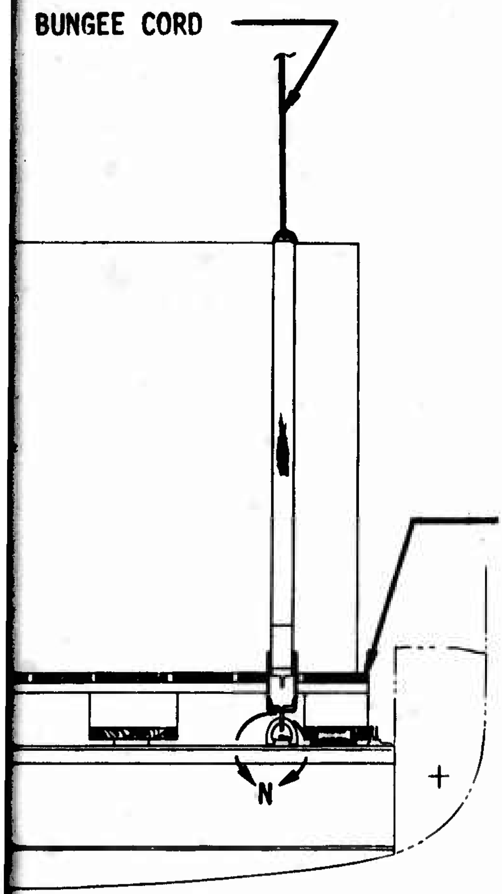
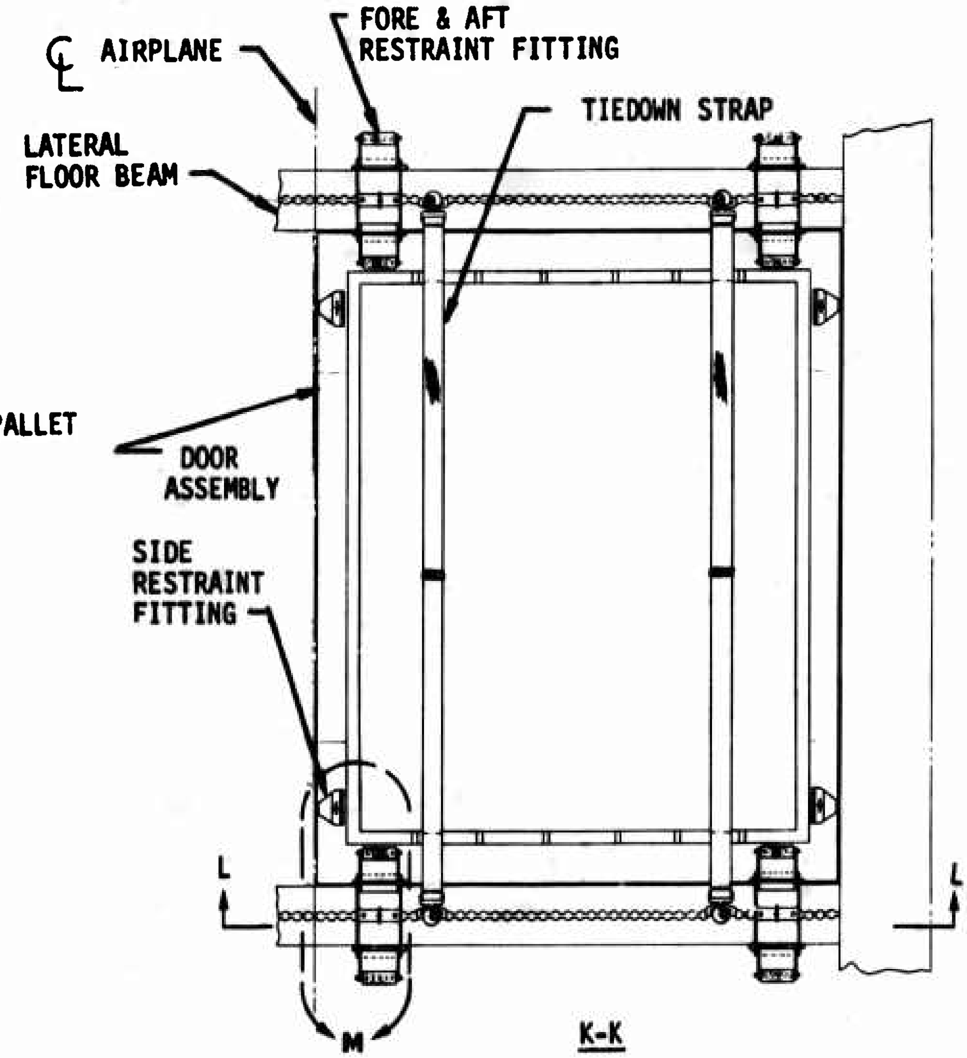


Figure 25. (U) Restraint of Palletized Air-Land Cargo — V/M Cargo Handling System III.


BUNGEE CORD
RELEASE RING
LATERAL FLOOR BEAM
N
PLUG-IN TIEDOWN RING
"T" BAR SUPPORT
PALLET
N
L-L
FORE & AFT RESTRAINT FITTING
LATERAL FLOOR BEAM
RESTRAINT POSITION FOR AIR-LAND PALLETS (40" x 48")
(43" x 52")
℄ AIRPLANE
FORE & AFT RESTRAINT FIT
LATERAL FLOOR BEAM
DOOR ASSEMBLY
SIDE RESTRAINT FITTING
L
M

2


BUNGEE CORD
PALLET
N
L-L


℄ AIRPLANE
FORE & AFT
RESTRAINT FITTING
TIEDOWN STRAP
LATERAL
FLOOR BEAM
DOOR
ASSEMBLY
SIDE
RESTRAINT
FITTING
L
L
M
K-K

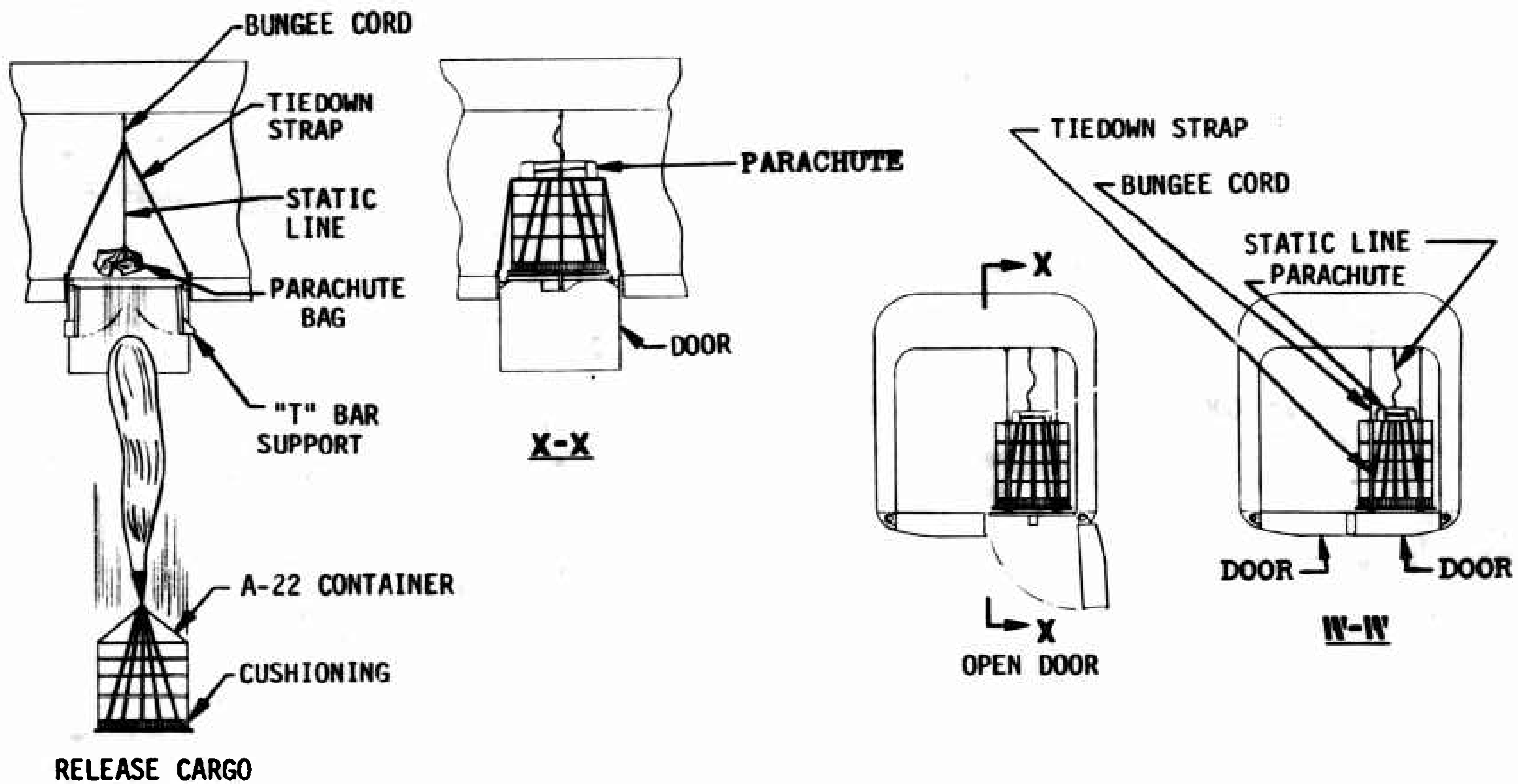
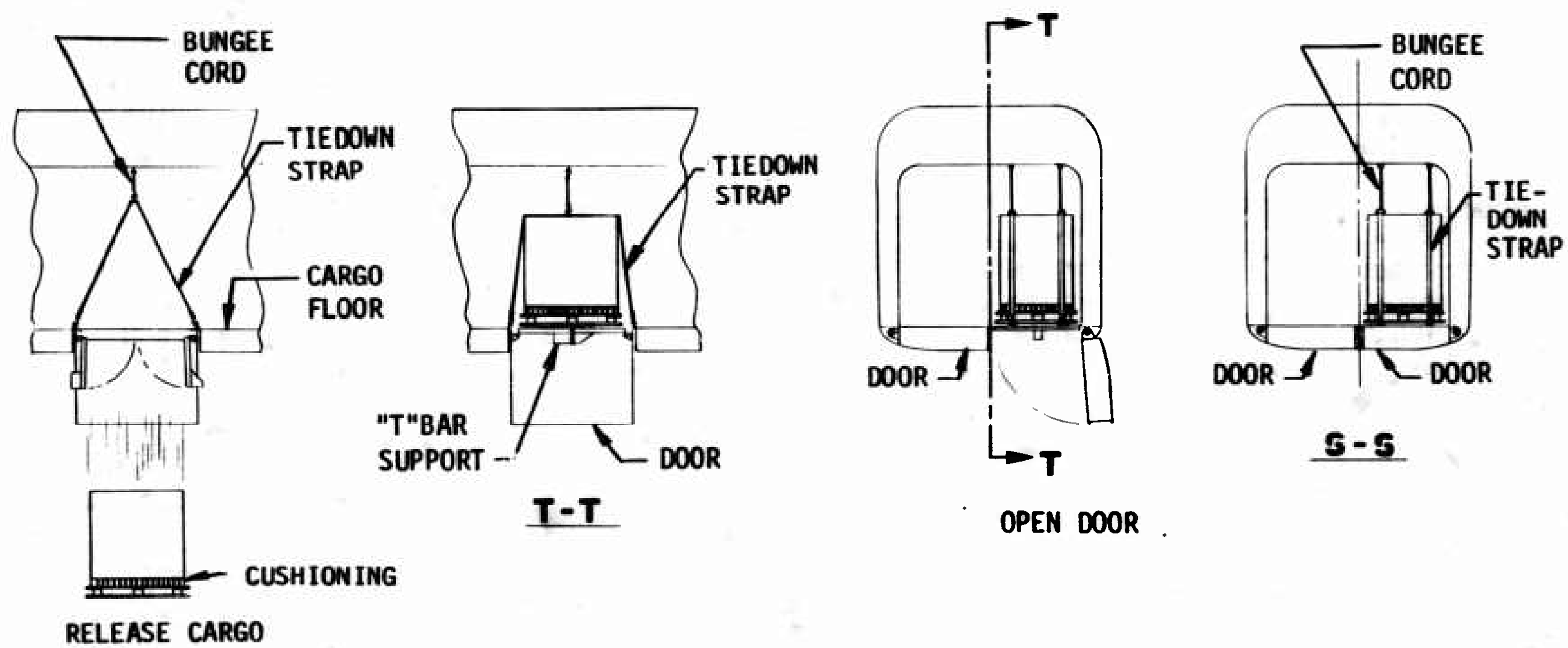


Figure 26. (U) Airdrop Function of V/M Delivery System III.



CARGO RIGGING IS SHOWN FOR HOVER-DROP

Figure 27. (U) Hover-Drop Function of V/M Delivery System III.

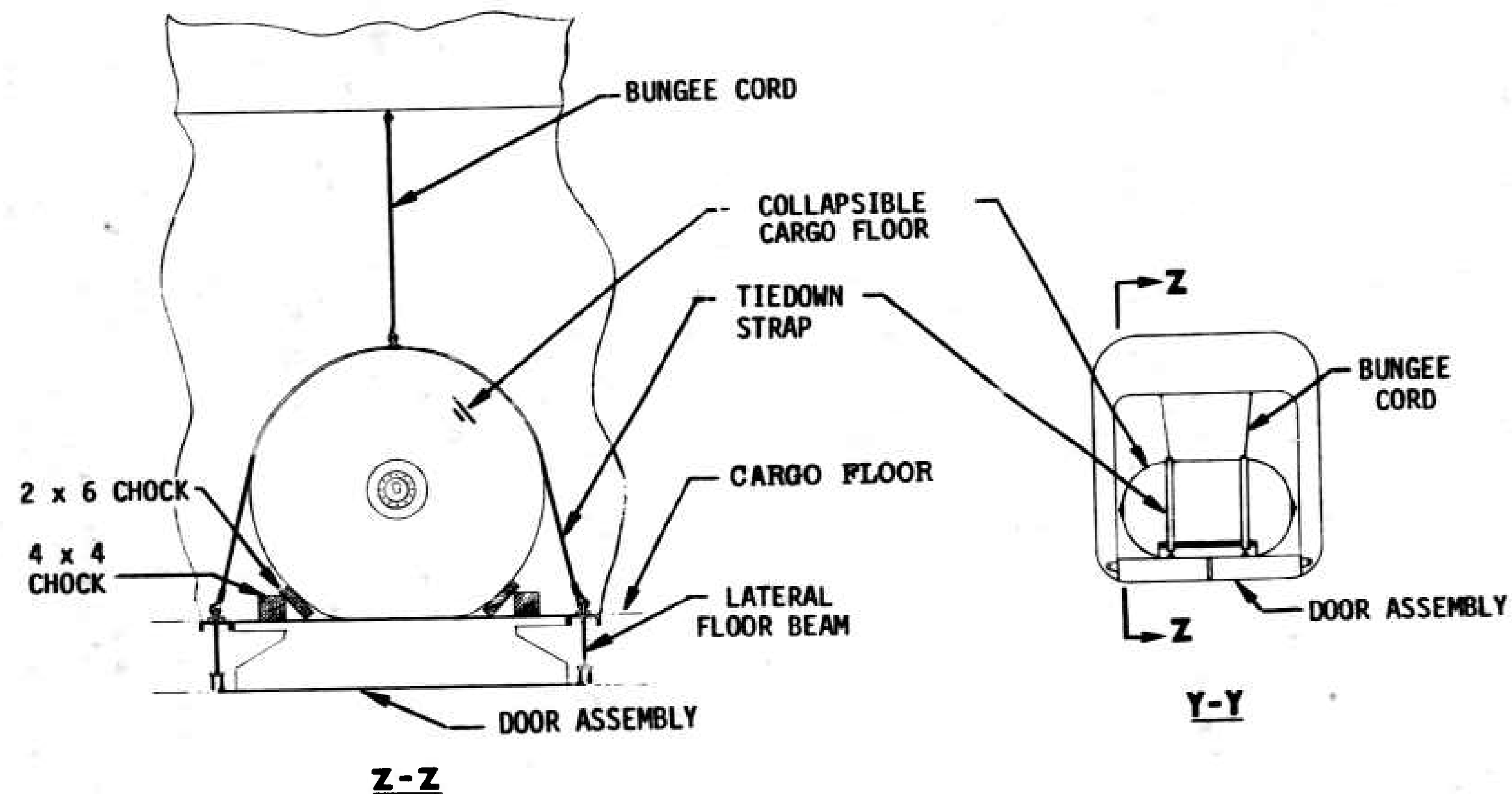


Figure 28. (U) Collapsible Fuel Drum Restraint with V/M Cargo Handling System III.

Tiedown Rings

Cargo tiedown rings have been used with this system to maintain the versatility to restrain various types of cargo such as bulk, vehicular, and palletized cargo.

S ongitudinal rows of tiedown rings are provided in the modified aircraft instead of the five rows currently installed in the floor of the existing aircraft. The additional row and the relocation of the tiedown rings were necessary because of the modification to the floor structure and the addition of bottom doors.

Four longitudinal rows of tiedown rings are permanently installed in the cargo floor and door assemblies. They are spaced 20 inches on center, both laterally and longitudinally, starting 10 inches on either side of the centerline of the aircraft. Plug-in type tiedown rings are attached into the key slots in the lateral floor beams, in line with the four rows, to maintain the continuity of the 20-inch spacing. These tiedown rings are quickly removed and stowed within the aircraft when not in use (see Figure 25).

An additional row of permanently installed tiedown rings is located along each outboard edge of the cargo floor. The rings are attached to the fuselage side structure and are in line with the rings in the cargo floor, the door assemblies, and the lateral floor beams.

Seat Studs

The capability to transport troops and litter patients has been retained with the aircraft by providing a pattern of seat studs for troop seat and litter stanchion attachment.

The seat studs are integrated into the floor and door structure by utilizing recessed pans and slots in the lateral floor beams.

Airdrop Sequence Control

Existing aircraft which employ the conventional rear-end extraction concept for multiple module airdrop have only one sequence for discharging cargo; the last load on is first off, etc. Therefore, the loadmaster can predetermine and control the center-of-gravity shift for the discharging of a full or a partial aircraft load. Once the aircraft load buildup has been determined and the modules loaded, the sequence of airdropping various cargo is unchangeable. This disadvantage is removed with the vertical/modular delivery system, which can vary the sequence of load release.

The airdrop control sequence system consists of three major subsystems: a module weight sensor; a center-of-gravity computer and c. g. limit comparator; and a door control and module release panel. The system is capable of calculating and predetermining the c. g. location of the aircraft loads after any one or combination of modules would be airdropped. The system will also control the opening of the doors and the airdropping of those modules which would not jeopardize the safety of the aircraft.

The basic principle of the system involves sensing the load on each of the cargo compartment doors and then resolving these forces into a c. g. location relative to the aircraft. The sensing element will consist of strain-gage transducers installed in each module compartment door so that they will react only to cargo loads placed in that compartment. The transducer output is an electrical signal proportional to the weight of the load in each cargo compartment and can be used in a computer to solve the following equation:

$$\text{c. g.} = \frac{\text{OWE}\,(\text{C.G.}^{1}) + L_1\,(X_1) + L_2\,(X_2) + \ldots + L_n\,(X_n)}{\text{OWE} + L_1 + L_2 + \ldots\ L_n} \qquad (1)$$

Where OWE = Operating weight empty of the aircraft

C. G.^{1} = Center of gravity of the aircraft empty

L_n = Weight or load in the nth compartment

X_n = Distance from the nose to the nth compartment

Since the distances (X_n) are constant, they can be expressed as fixed values, and the weights are available as proportional voltages from the sensor. Obtaining the center of gravity involves several additions, products, and a quotient. The electrical output voltages from the sensors are used only once, when the aircraft is on the ground fully loaded. This static load value is memorized by the computer and is used for all calculations from that point on until the load is finally dropped. Using the static load value for all computations eliminates the possibility of ambiguity in the computer calculations as the result of changing load values caused by the aircraft being in a flight condition.

Calculation of the c. g. with all loads present is only an initial function of the computer. The computer's primary function is to determine what loads the pilot can drop and still maintain the c. g. within the specified limits of the aircraft. The computer will accomplish this by making eight computations simulating one load going to zero for each computation. For instance, in order to determine whether or not L_1 can be dropped without the c. g. going out of limits, the computer must first simulate that L_1 is zero and then make a calculation using the foregoing equation and L_1 being equal to zero. After this calculation is complete, it is necessary to compare the result to determine that its value is greater than the lower limit and less than the upper limit. If the result falls within the limits, an indication must be given to the pilot telling him that L_1 is a safe load to drop.

This is accomplished by a green indicator light coming on the control panel, which consists of an array of lights and switches. If the result comes up with an unsafe condition, a red indicator light would come on. The computer would then go on to its second calculation, but this time it would simulate that L_2 would be equal to zero instead of L_1 and then go through the same

steps as it did when simulating L_1 to be zero. After the computer had gone through 8 calculations, each time simulating a different load to be zero, the control panel would have green lights on for those loads which, when dropped, would (1) not shift the c. g. out of the specified limits and (2) have red lights on for those loads that would shift the c. g. out of the specified limits.

At this point, the computer would be inactivated, since all values of parameters would remain constant. This condition would exist until the pilot had dropped one of the loads which had previously been shown safe to drop. Dropping of the load would then reactivate the computer so that it would start making calculations again. Only this time, the value used for the load which had just been dropped would be zero in all the calculations and the computer would have to make 7 calculations instead of 8. The control panel would then again indicate to the pilot those loads which he could drop safely. The computer would follow the same procedure until all loads had been dropped.

The condition which has been described so far has been one where each cargo compartment load has been released one at a time. The situation does exist where two or more compartments must be released at the same time, such as in the case of fuel containers whose size is large enough to take up two cargo compartments. This presents a different problem to the computer since, even if it did indicate that either load could be dropped, it only considered that one load would be released at a time. Therefore, the system must be such that the pilot can manually program the computer with this condition and then receive an indication as to whether or not this would be a safe condition. This operation is done by the pilot depressing, on the control panel, those switches for the loads he wants to drop, thus causing the computer to be reactivated to make another calculation. Only this time, the computer will simulate those loads to be zero corresponding to the switches that have been depressed. Instead of running through a number of calculations, the computer will run through only one calculation and light a separate indicator determining whether the condition is safe or unsafe. The indicator lamps for the separate loads will not be disturbed during this operation so that if the condition is unsafe, the pilot can still determine which loads can be dropped singly.

The system will have the computer tied into the door opening valve circuit to maintain the capability of not being able to drop a load which could cause an unsafe condition. When the computer makes a calculation and determines that a load can be dropped safely, the door opening valve to that load will be activated so that when given the command, the valve will be able to open. If, on the other hand, the computer determines that the load cannot be dropped safely, the circuit will be inhibited from opening the door if the pilot has accidentally given that particular compartment a door-open command. The inhibit command can be overridden in the case where a multiple drop has proven to be safe, yet one or both loads has proven to be unsafe in a single drop.

(U) STRUCTURAL CONSIDERATIONS

Structural modification to provide airdrop of palletized cargo through the floor of an aircraft fuselage will impose a weight penalty on the basic airframe. The magnitude of this penalty is dependent upon the size, number, and location of the openings.

A structural weight trade-off study was performed on an airframe configuration as represented by the XC-142A aircraft. The scope of this program encompassed the following items:

- Description of basic structure
- Structural arrangements for airdrop study
- Load analysis for selected configurations
- Airframe weight comparison
- Airframe structrual stiffness comparison

Detailed discussions of each item are presented in the following paragraphs.

DESCRIPTION OF BASIC STRUCTURE

The fuselage is a semimonocoque aluminum alloy structure composed of two upper longerons, a longitudinally stiffened cargo floor, bulkheads, frames, and cover skins. The major load-carrying frames are machined forgings. The balance of the structure consists of sheet metal and extruded detail parts.

The center section of the fuselage has cutouts in the lower surface and the cargo floor. The section is 30 feet long and extends from the aft limit of the pilot's enclosure to the forward end of the cargo ramp.

Cargo Floor

The cargo floor is a longitudinally stiffened panel supported by fuselage frames (lateral floor beams). A typical cross section of the floor structure is shown in Figure 29. The stiffeners and frames (lateral floor beams) are spaced to provide a 20-inch grid pattern for the cargo restraint system.

The cargo floor structure is designed to withstand a 300-pound-per-square-foot load. This load is normal to the basic load paths of the fuselage, and the required strength of the floor is not fully effective in resisting the airframe loads due to shear lag in the cargo floor panels.

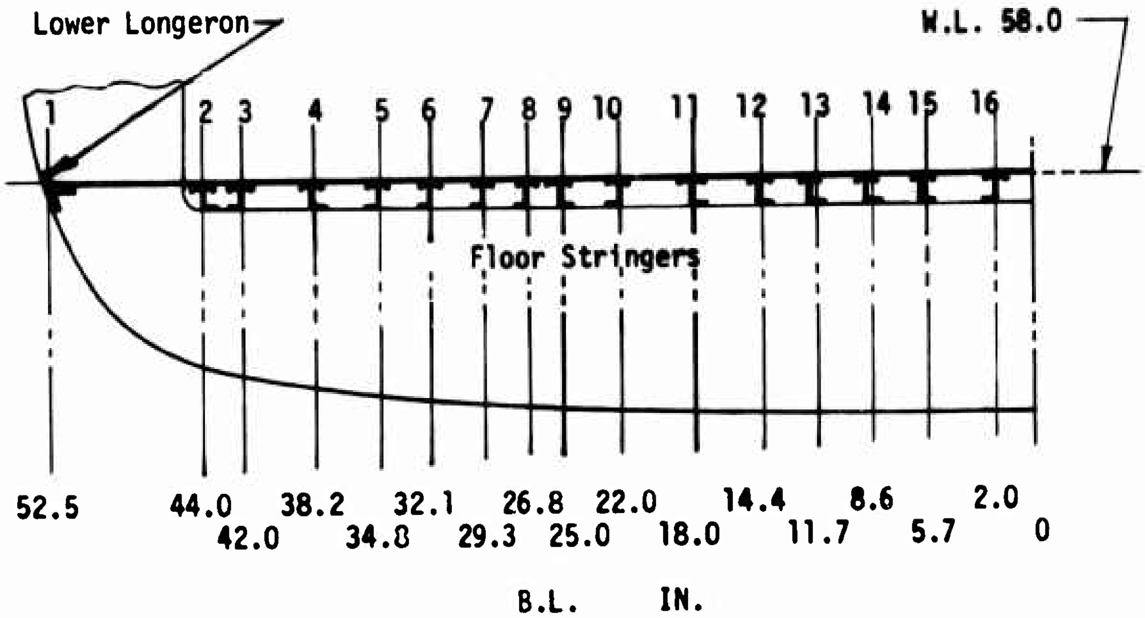


Figure 29. (U) Cargo Floor Structural Arrangement.

Minimum Gage Structure

The XC-142A fuselage contains structural elements that are minimum gage as specified by applicable military specifications. These non-optimum structural items consist of lightly loaded skin panels, stiffeners to damp out panel flutter, and minimum thicknesses for extrusions or machined parts. An increase in loads would not reflect a proportional increase in weight until the full strength of the minimum gage structure has been reached.

Main Landing Gear

The support structure and external fairings for the main landing gear on the XC-142A aircraft will interfere with the installation of an airdrop exit door. For the parametric study, it was assumed that this area can be reconfigured at a comparative weight.

STRUCTURAL ARRANGEMENTS FOR AIRDROP STUDY

Preliminary studies have shown that two structural arrangements are feasible for a palletized airdrop system: (1) The first arrangement provides for a double row of pallets to be dropped individually through doors spaced longitudinally along the cargo floor centerline. A maximum of ten 40 x 48 pallets or five collapsible fuel drums can be accommodated. The fuel drums would be loaded normal to the cargo floor centerline and dropped by opening two doors. (2) The second arrangement provides for a single row of pallets to be dropped individually through doors on the cargo floor centerline. A maximum of six pallets or three fuel drums could be accommodated.

The basic fuselage center section structural arrangement is utilized for the two cargo airdrop systems. The major structural revisions involve the cargo floor structure and supporting frames (lateral floor beams), and the fuselage lower surface.

The torsional spring rate of the fuselage structure will be reduced due to the cutouts in the lower segment of the basic structure. A keel box was added to each side of the fuselage adjacent to the cutout to minimize this reduction.

Airframe Configuration for a Double Row of Pallets

The openings through the cargo floor and the fuselage lower surface for the double-row configuration are 90 inches wide and 55 inches long. Two full-depth 45-inch-wide by 55-inch-long doors, hinged at the outboard edge, are utilized to replace the floor structure and its support. The lower segment of a fuselage frame (lateral floor beam) located at each end provides a door jamb, a support for the latching mechanism, and a seal.

The forward limit for cutouts in the cargo floor was established at fuselage station 130 to preserve the entrance door and emergency escape hatch

structure. The aft location was limited to fuselage station 430 to maintain structural integrity for the support of the aft loading ramp. The total length available for cutouts is 300 inches.

The 20-inch frame spacing of the basic configuration is sufficient for a 5-inch-wide frame cap structure across the fuselage between each set of the 55-inch-long doors. This cap width provides sufficient stiffness to support the frame (lateral floor beam) compression loads. The keel box extends from stations 130 to 430 and from the edge of the cargo floor cutout to the outer vertical skin panel of the fuselage.

A significant relationship exists between the number of cutouts and their location with respect to the aircraft center of gravity. Preliminary studies indicated that four pallets in a double-row configuration should be the minimum number considered. The location of the two cargo floor full width cutouts and the resulting structural arrangement for this configuration are shown in Figure 30. The structural arrangements for three, four and five similar full-width cutouts are shown in Figures 31 through 33 respectively.

Airframe Configuration for a Single Row of Pallets

The openings through the cargo floor and the fuselage lower surface for a single row of pallets are 55 inches wide and 95 inches long. Two full-depth 27.5-inch-wide by 95-inch-long doors, hinged on the outboard edge, are used to replace the cargo floor and its support structure. The lower segment of a fuselage frame (lateral floor beam) located at each end provides a door jamb, a support for the latching mechanism, and a seal.

The 20-inch frame spacing of the basic airframe is sufficient for a 5-inch-wide frame cap structure across the fuselage between each set of the 95-inch-long doors.

The cargo floor area remaining between the edge of the cutouts and the vertical side panels of the fuselage will be utilized as the keel box structure by adding a longitudinal shear web at the edge of the cutouts and increasing the gage of the lower skin.

The number of cutouts and their location were coordinated with the aircraft center of gravity. Structural arrangements for one, two and three cutouts are shown in Figures 34, 35 and 36.

Cargo Floor Door Configurations

The doors for both airframe configurations are full depth, utilizing the existing cargo floor cross section and support structure arrangement. Longitudinal shear webs were added to the inboard and outboard edges of the door to complete the structural arrangement. All of the doors are supported by hinge fittings at the appropriate fuselage frame (lateral floor beam) and are actuated by hydraulic rotary actuators located at the two

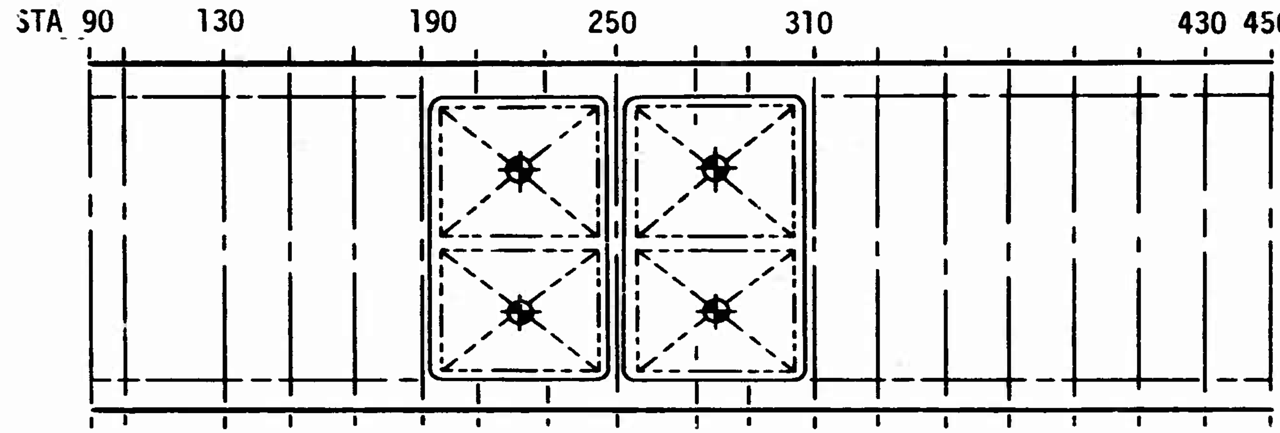


Figure 30. (U) Structural Arrangement for Double Row of Four 40 x 48 Cargo Pallet Exits.

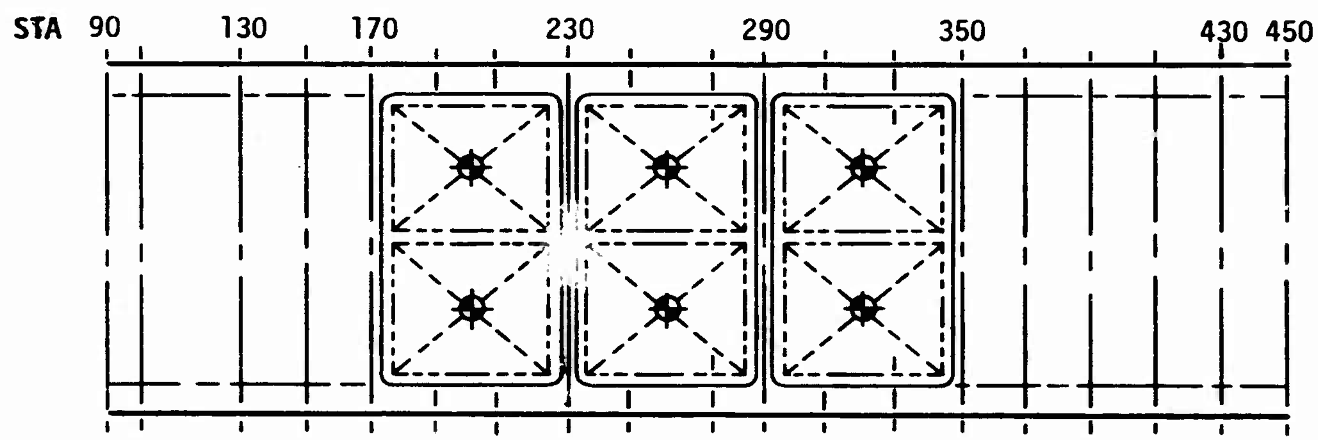


Figure 31. (U) Structural Arrangement for Double Row of Six 40 x 48 Cargo Pallet Exits.

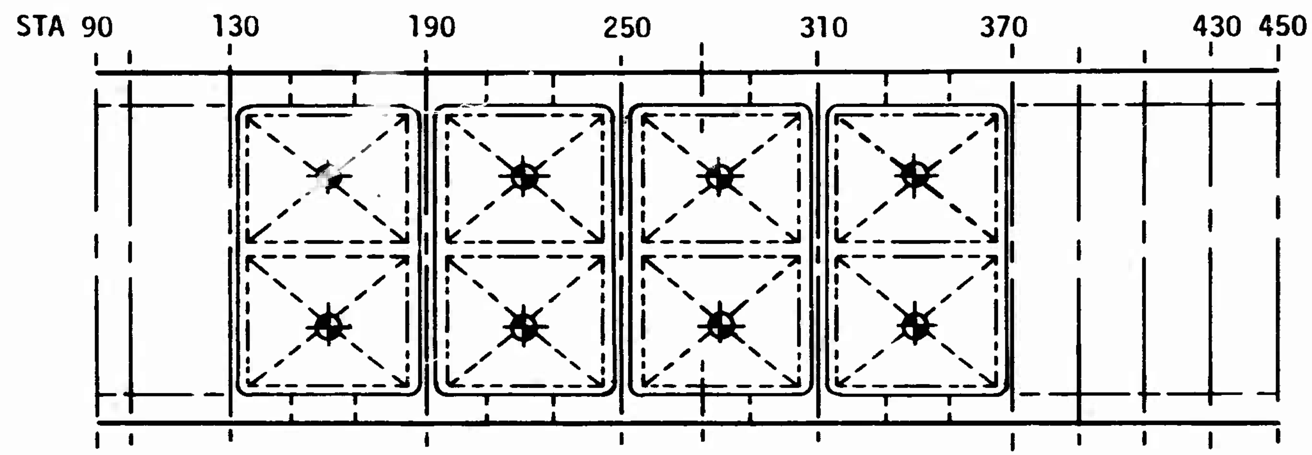


Figure 32. (U) Structural Arrangement for Double Row of Eight 40 x 48 Cargo Pallet Exits.

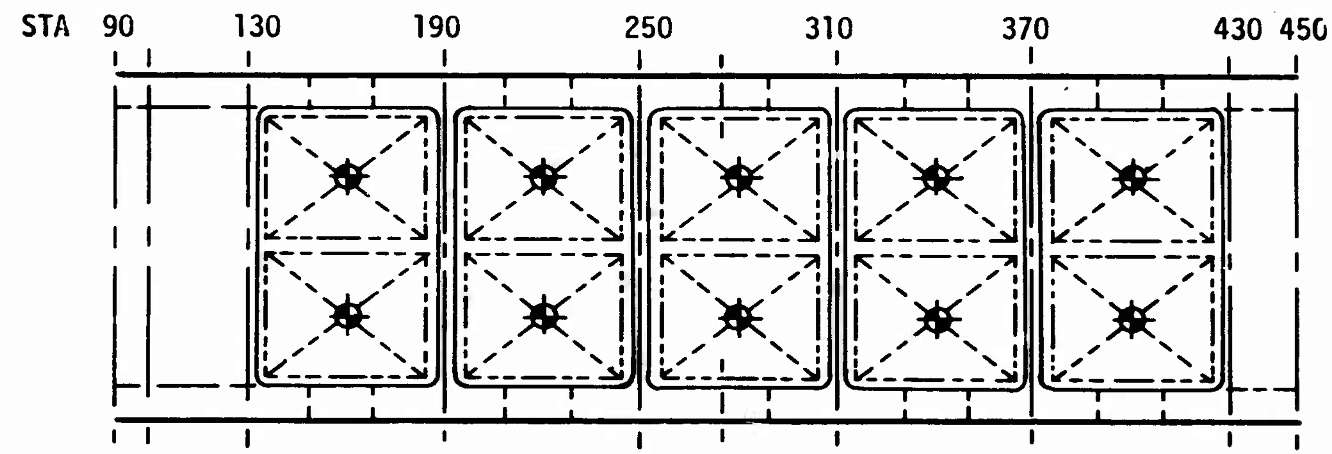


Figure 33. (U) Structural Arrangement for Double Row of Ten 40 x 48 Cargo Pallet Exits.

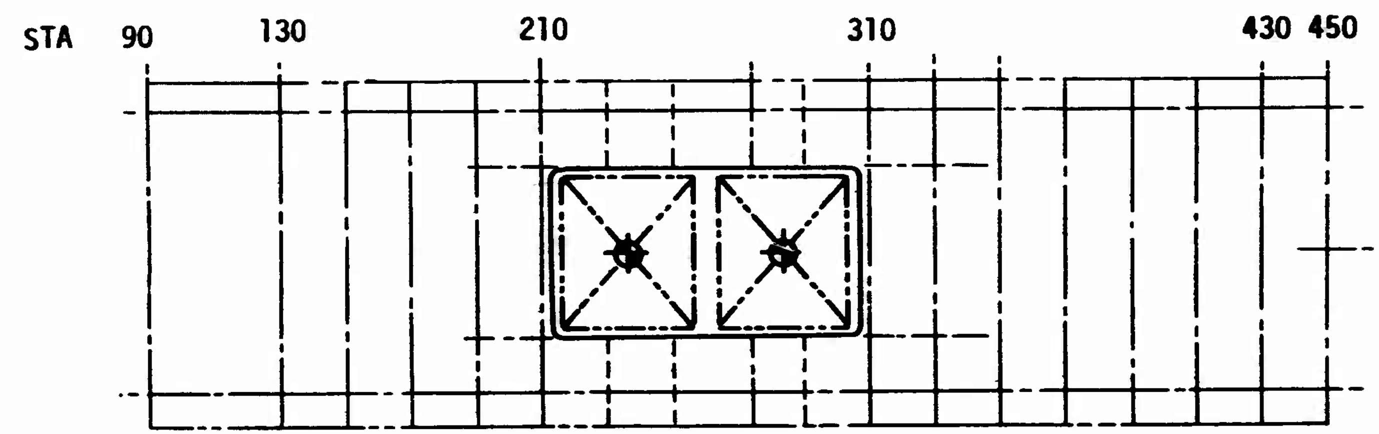


Figure 34. (U) Structural Arrangement for Single Row of Two 40 x 48 Cargo Pallet Exits.

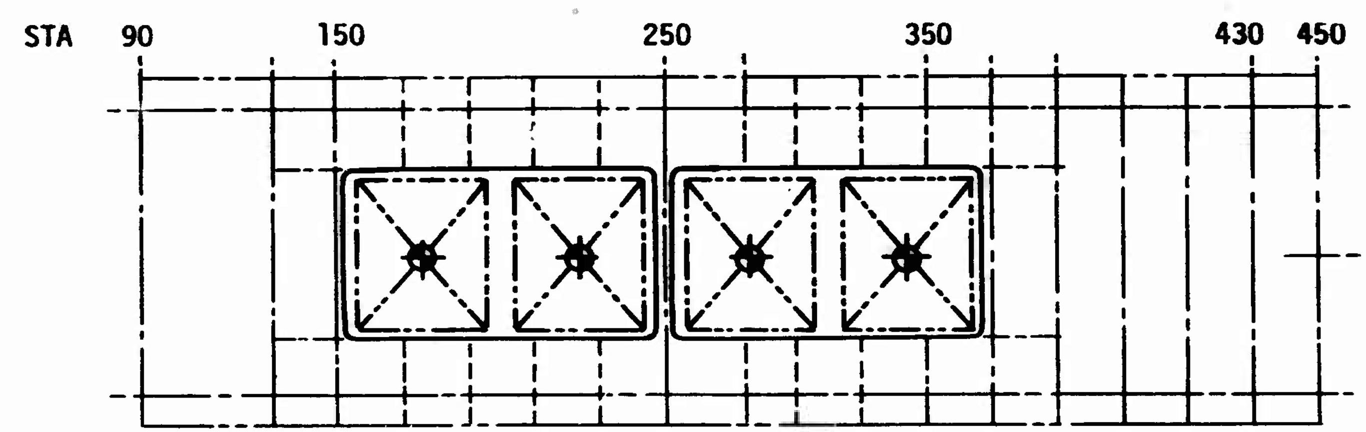


Figure 35. (U) Structural Arrangement for Single Row of Four 40 x 48 Cargo Pallet Exits.

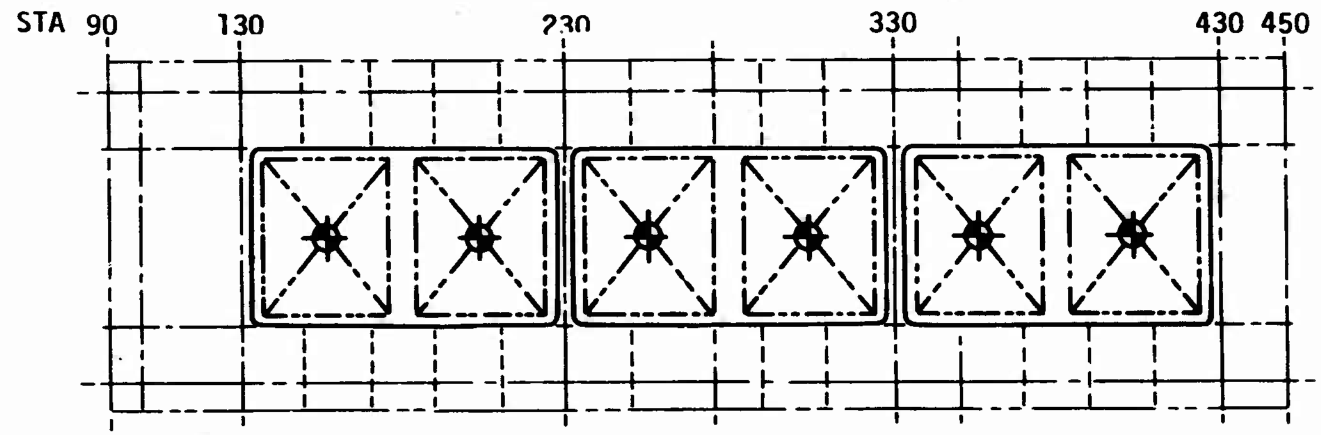


Figure 36. (U) Structural Arrangement for Single Row of Six 40 x 48 Cargo Pallet Exits.

center hinge stations of each door configuration. The doors are latched in the closed position by a hydraulically operated over-center mechanism mounted on the lower segment of the fuselage frame (lateral floor beam) located at the ends of each door.

LOAD ANALYSIS FOR SELECTED CONFIGURATIONS

The portion of the fuselage structure under consideration has critical strength margins at several locations due to various loading conditions. The most critical cases were selected from Reference 61. A fuselage torque load condition was added to determine the torsional stiffness of the structure. An additional loading condition was included which requires door support of the cargo load through the actuating system when the doors are unlatched.

The shear, moment, and torque curves for the loading conditions are shown in Figures 37 through 42. These curves were taken from Reference 61. The distribution of the vertical and horizontal components of the fuselage external loads are noted in Tables VIII and IX. The identification and location of the load components are shown schematically in Figures 43 and 44.

The various fuselage external loads were resolved into joint loads for the entire center section of the fuselage. The location of each load for the three structural arrangements is shown in Figure 45. The magnitude of each, for all loading conditions, was determined and used as input data for the parametric weight analysis.

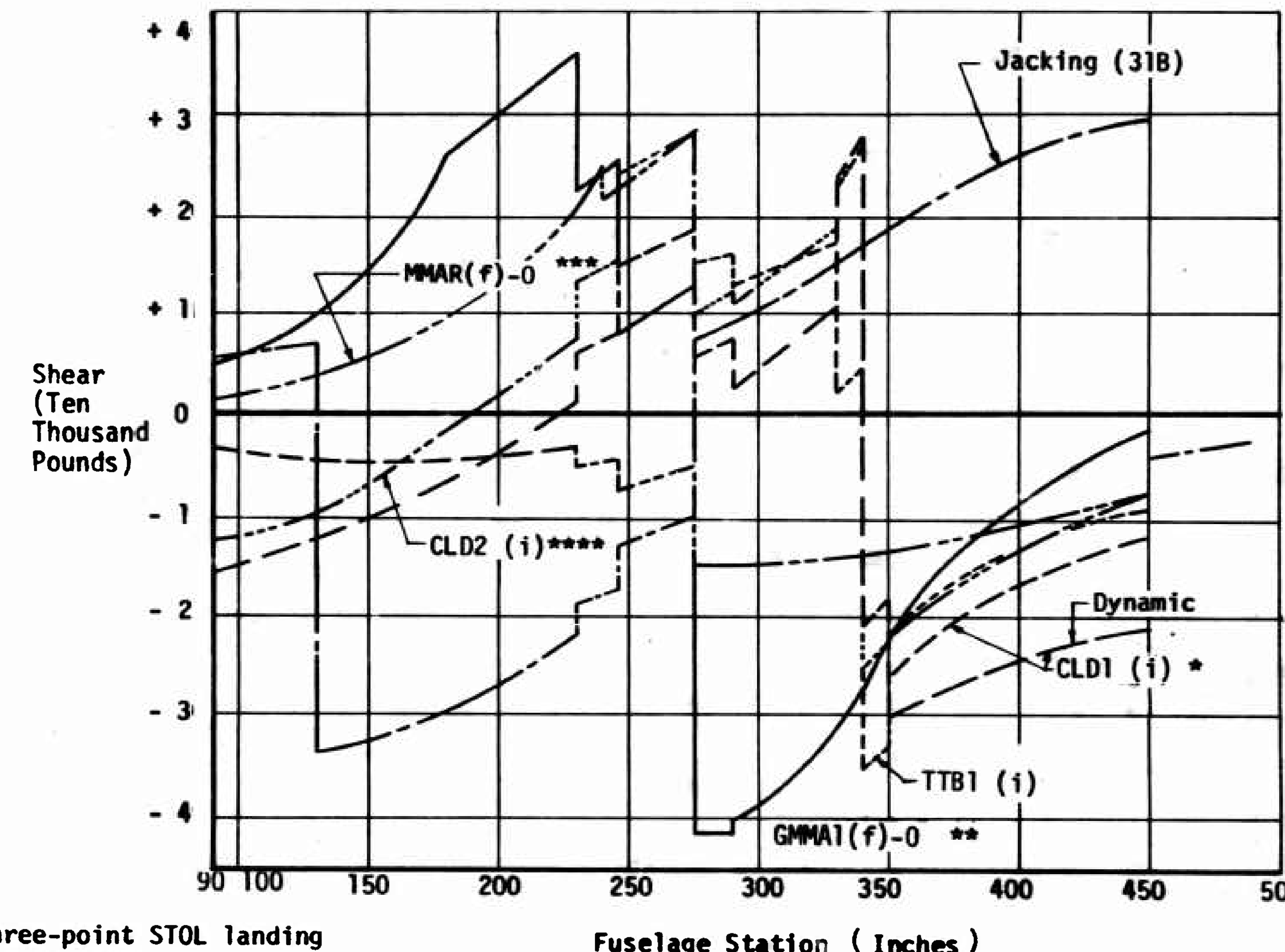
Symmetrical Three-Point STOL Landing Loads

The spin-up loads from the main landing gear cause critical shears in the aft fuselage side panels. The dynamic response of the structure increases the bending moments and shears in the aft section of the fuselage.

Superimposed on this condition is the 300-pound-per-square-foot cargo floor load requirement. This load determines the strength requirements for the lower segments of the fuselage frames (lateral floor beams) and was added in a manner that did not change the basic landing loads.

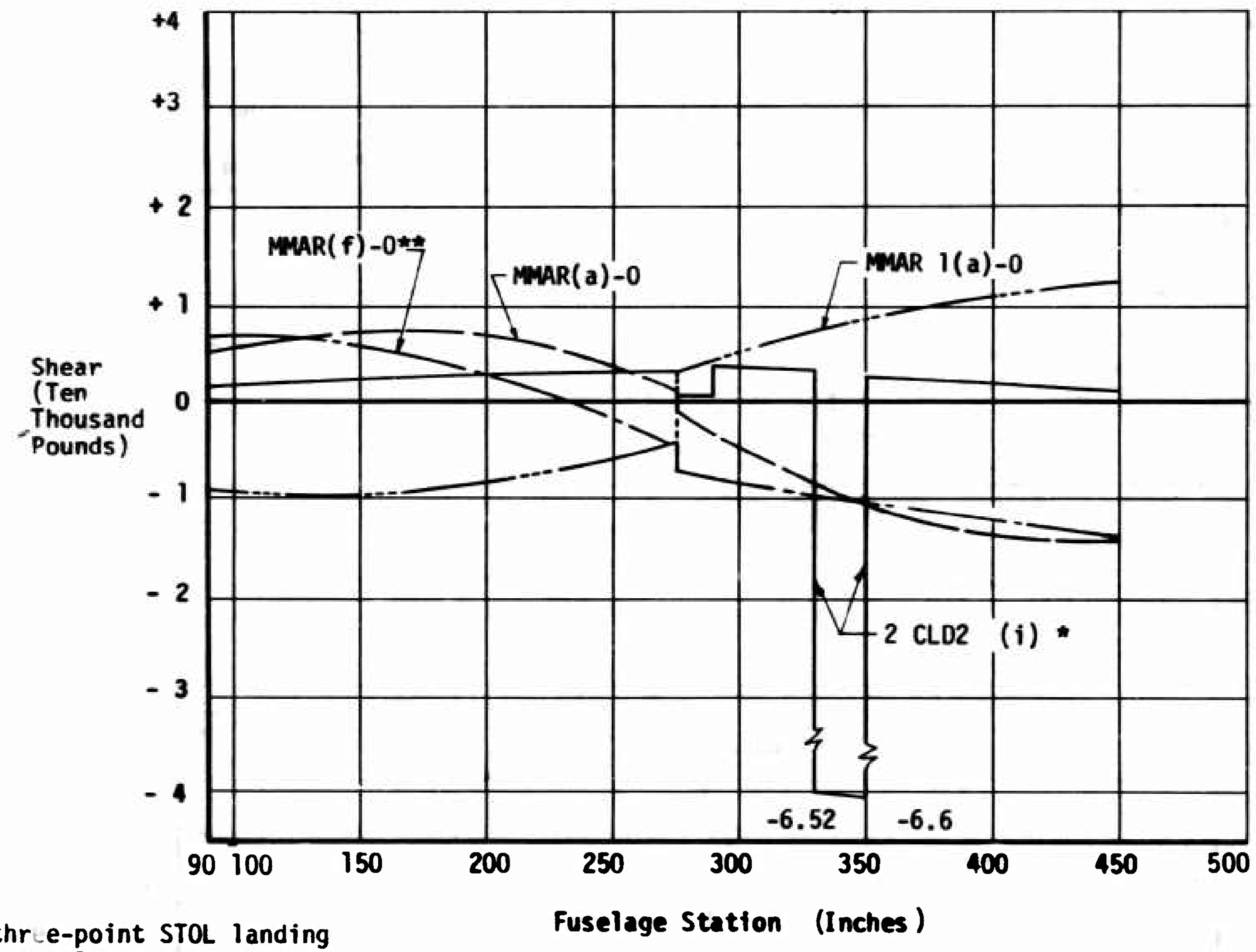
Jacking Loads

The aircraft at full gross weight is supported by a jack at each corner of the fuselage center section. The maximum negative bending moments are imposed on the fuselage by this loading condition.



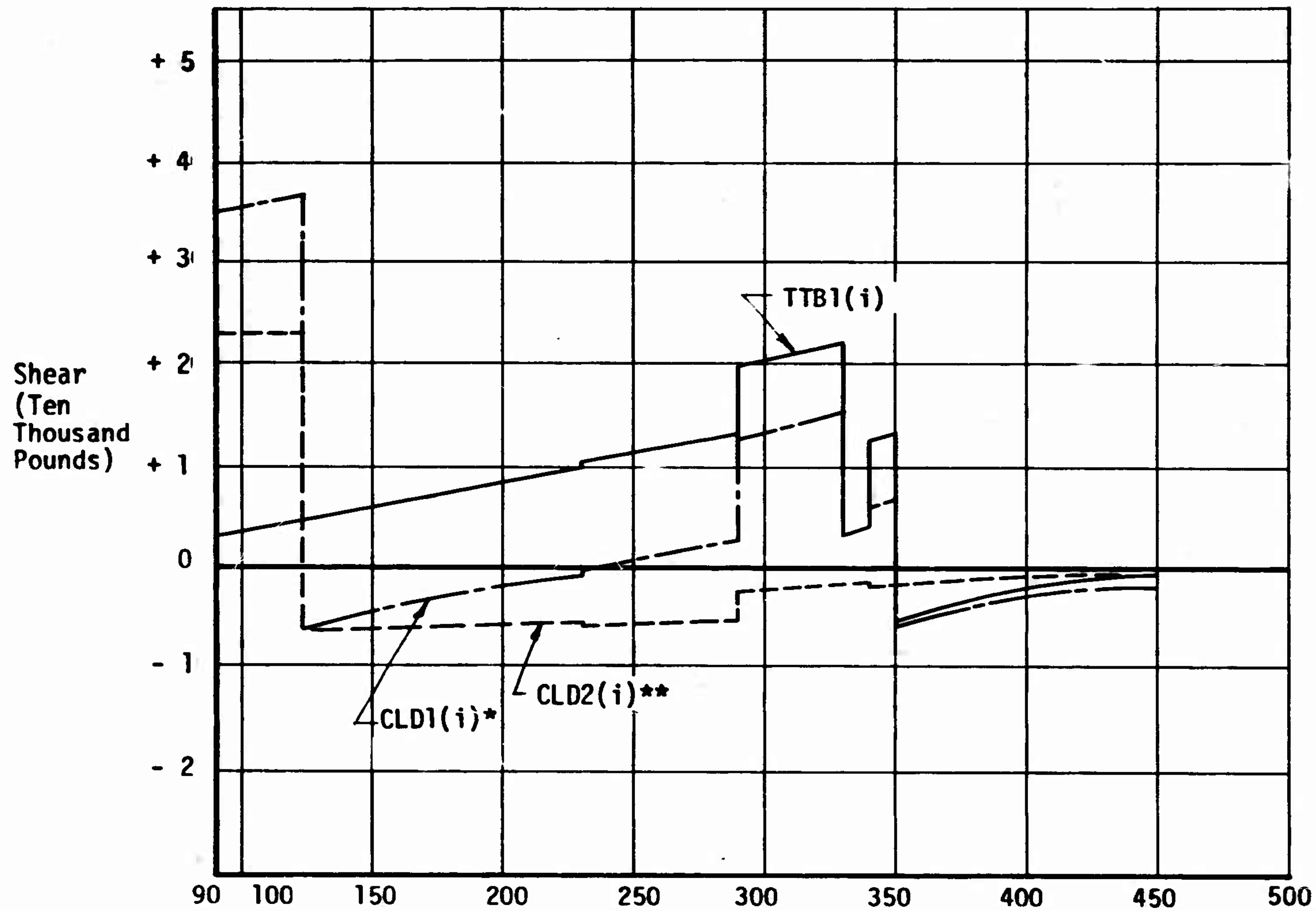
* Sym three-point STOL landing
** Sym flight gust
*** Anti-sym flight gust
****Out-of-phase main landing gear loads

Figure 37. (U) Limit Vertical Shear Loads on Fuselage Due to Various Loading Conditions.



* Sym three-point STOL landing
** Anti-sym flight gust

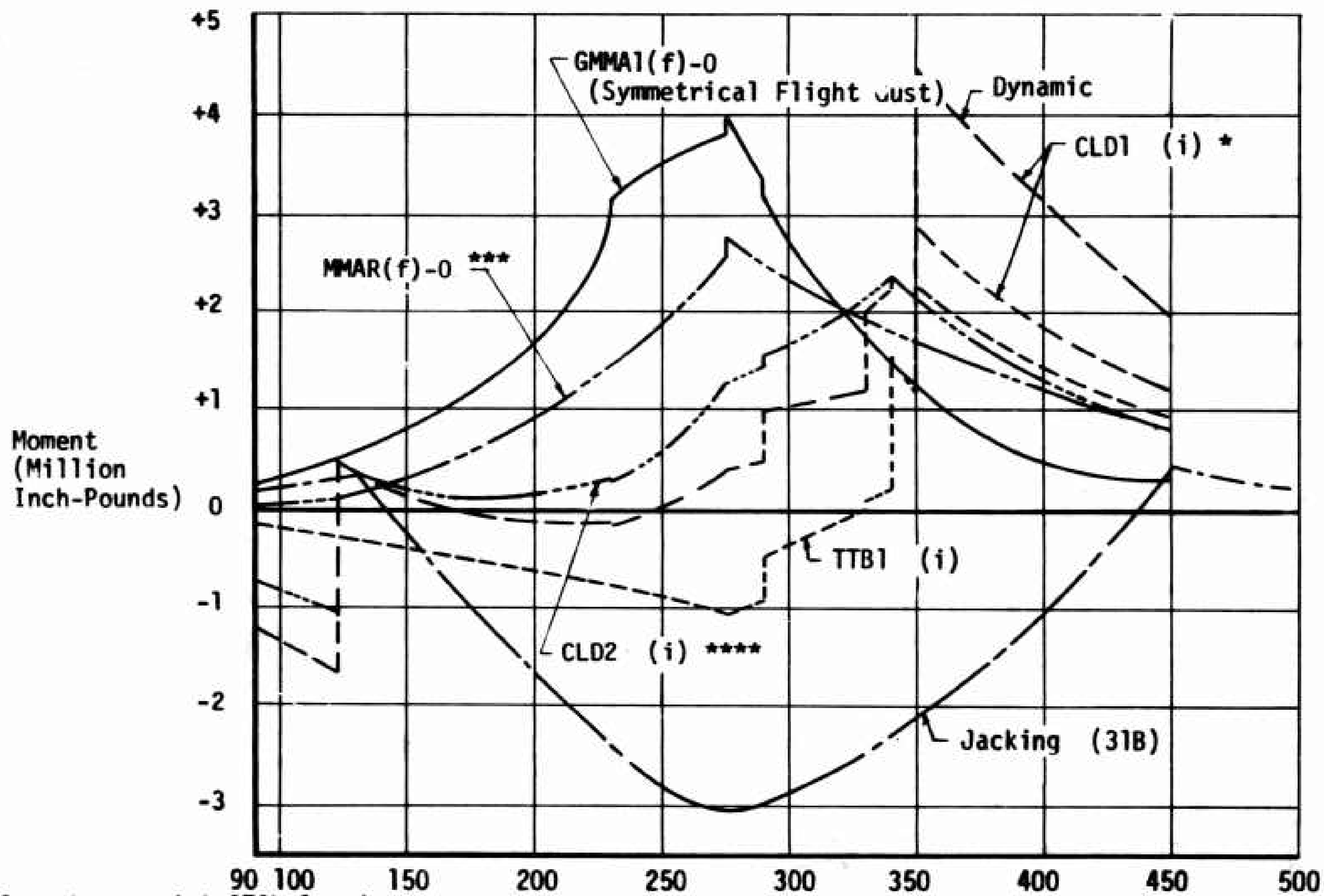
Figure 38. (U) Limit Horizontal Shear Loads on Fuselage Due to Various Loading Conditions.



* Sym three-point STOL landing

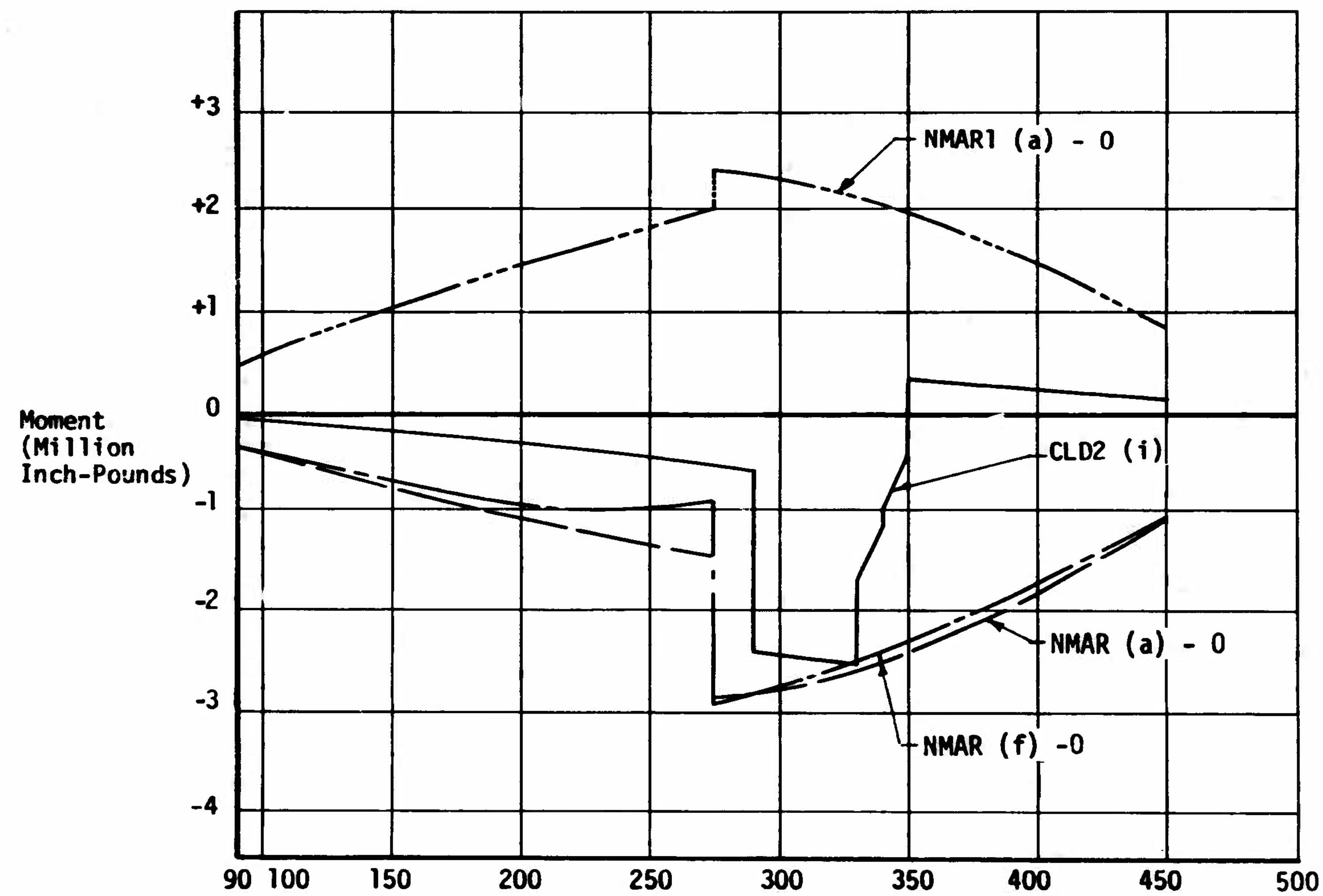
** Out-of-phase main landing gear loads

Figure 39. (U) Limit Longitudinal Shear Loads on Fuselage Due to Various Loading Conditions.



* Sym three-point STOL landing
** Sym flight gust
*** Anti-sym flight gust
**** Out-of-phase main landing gear loads

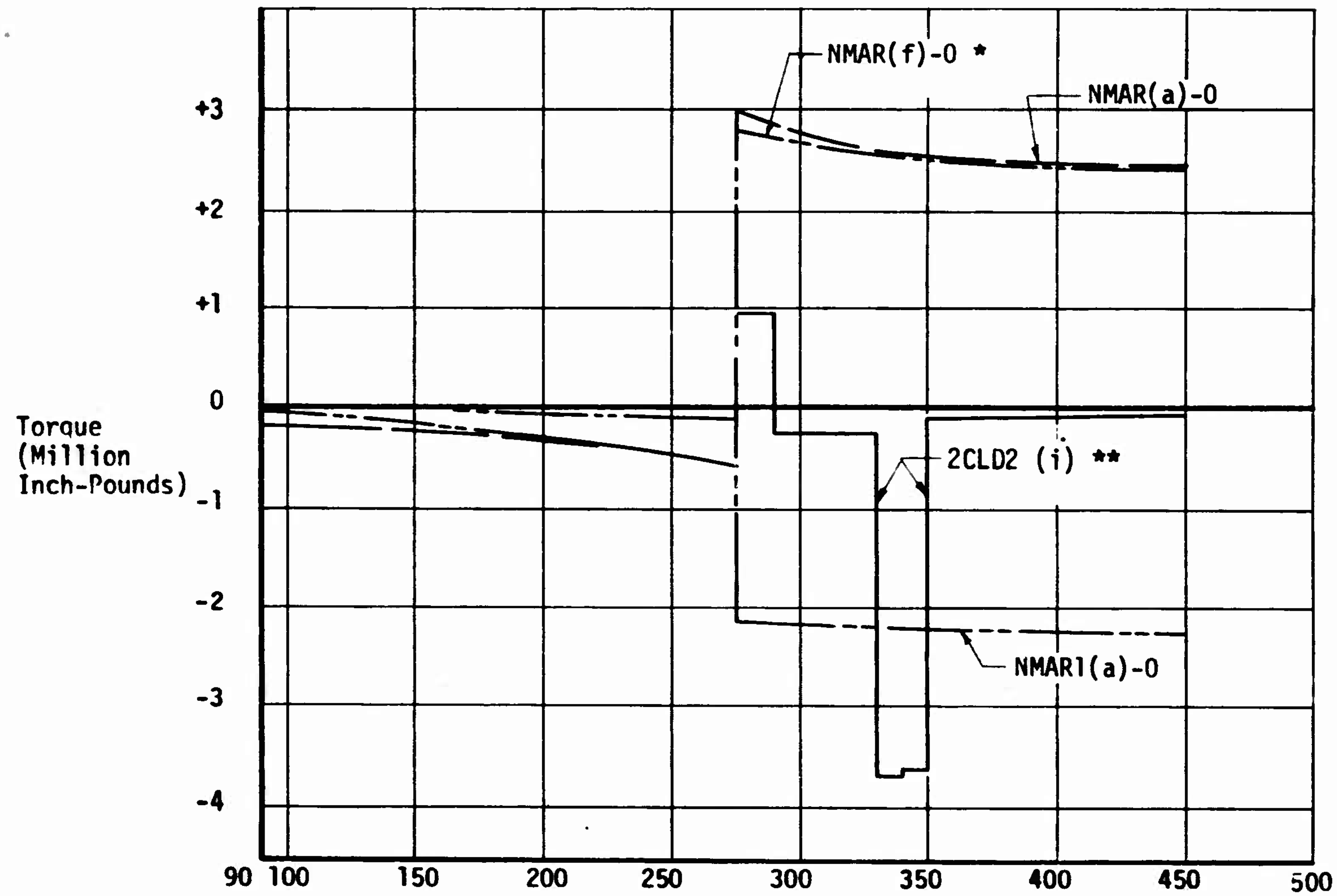
Figure 40. (U) Limit Vertical Moments on Fuselage Due to Various Loading Conditions.



* Anti-sym flight gust

** Out-of-phase main landing gear loads

Figure 41. (U) Limit Horizontal Moments on Fuselage Due to Various Loading Conditions.



* Anti-sym flight gust
** Out-of-phase main landing gear loads

Figure 42. (U) Limit Torque on Fuselage Due to Various Loading Conditions.

TABLE (U)

EXTERNAL HORIZONTAL LOAD DISTRIBUTION FOR FUSELAGE

Load Component No.	Loading Condition 1 Load (lb)	1 Sta (in.)	2 Load (lb)	2 Sta (in.)	3 Load (lb)	3 Sta (in.)	4 Load (lb)	4 Sta (in.)
1	16000	90	—	—	11500	90	—	—
2	11500	90	- 2000	90	1000	90	—	—
3	11500	450	- 2000	450	1000	450	—	—
4	5000	274	21420	274	2000	274	—	—
5	5000	274	-17420	274	2000	274	—	—
6	2000	340	—	—	1180	340	—	—
7	2000	340	—	—	- 1180	340	—	—
8	13000	340	—	—	16080	340	—	—
9	13000	340	—	—	-16080	340	—	—
10	—	—	13500	450	- 4336	450	4500	450
11	33762	330	—	—	40150	330	-38200	330
12	22597	350	—	—	28550	350	-47500	350
13	33762	330	—	—	-28400	330	—	—
14	22597	350	—	—	-40000	350	—	—
15	3300	340	—	—	3700	340	—	—
16	3300	340	—	—	3700	340	6950	340
17	—	—	*	90	***	90	—	—
18	—	—	**	450	****	450	—	—
19	43000	130	—	—	29000	130	—	—
20	—	—	7000	90	4336	90	- 2000	90
21	—	—	11500	210	—	—	—	—
22	—	—	3000	274	—	—	—	—
23	—	—	6000	380	—	—	—	—

* -0.35(10^6); ** -1.10(10^6); *** -0.05(10^6); **** 0.15(10^6); all are inch-pound moments

1. Sym three-point STOL landing
2. Anti-sym flight gust
3. Out-of-phase main landing gear loads
4. Main gear striking an obstruction

TABLE IX (U)

EXTERNAL VERTICAL LOAD DISTRIBUTION FOR FUSELAGE

Load Component No.	Sym Three-Point STOL Landing		Jacking		Sym Flight Gust		Anti-Sym Flight Gust		Out-of-P Main Lan Gear Lo
	Sta (in.)	Load (lb)	Sta (in.)	Load (lb)	Sta (in.)	Load (lb)	Sta (in.)	Load (lb)	Sta (in.)
1	90.0	6000	90.0	5500	90.0	4560	90.0	1630	90.0
2	-	-	108.0	1500	130.0	21000	-	-	-
3	150.0	23500	190.0	12000	200.0	9500	180.0	23500	170.0
4	240.0	2000	-	-	240.0	2500	-	-	-
5	262.3	4000	262.3	4500	262.3	5000	262.3	6500	252.3
6	310.0	9000	-	-	290.0	1000	-	-	302.3
7	400.0	9000	352.3	22500	362.3	38500	380.0	7500	400.0
8	450.0	21000	450.0	4000	450.0	1940	450.0	6870	450.0
9	90.0	19500	-	-	-	-	-	-	90.0
10	-	-	130.0	41000	-	-	-	-	-
11	328.6	13000	-	-	-	-	-	-	328.6
12	351.4	13000	-	-	-	-	-	-	351.4
13	-	-	450.0	34000	-	-	-	-	-
14	340.0	50000	-	-	-	-	-	-	340.0
15	274.5	17000	274.5	-17000	274.5	54000	274.5	43000	274.5
16	239.8	12000	239.8	8000	239.8	-30000	239.8	-3000	239.8
	Sta (in.)	Load (in.-lb)	Sta (in.)	Load (in.-lb)	Sta (in.)	Load (in.-lb)	Sta (in.)	Load (in.-lb)	Sta (in.)
17	90.0	$0.80(10^6)$	90.0	$0.20(10^6)$	90.0	$0.25(10^6)$	90.0	$0.05(10^6)$	90.0
18	450.0	$1.90(10^6)$	450.0	$0.45(10^6)$	450.0	$0.30(10^6)$	450.0	$0.80(10^6)$	450.0

GE

	Anti-Sym Flight Gust		Out-of-Phase Main Landing Gear Loads		Main Gear Striking an Obstruction		Sym Inverted Flight Gust		Cargo Loss on Unlatched Doors	
	Sta (in.)	Load (lb)	Sta (in.)	Load (lb)	Sta (in.)	Load (lb)	Sta (in.)	Load (lb)	Sta (in.)	Load (lb)
)	90.0	1630	90.0	6800	-	-	90.0	1500	-	-
)	-	-	-	-	-	-	143.4	-20800	-	-
)	180.0	23500	170.0	20000	-	-	240.0	-2200	160.0	5334
)	-	-	-	-	-	-	262.5	-3800	220.0	5334
)	262.3	6500	252.3	5000	-	-	282.3	-400	280.0	5334
)	-	-	302.3	11000	-	-	290.0	2100	340.0	5334
)	380.0	7500	400.0	14800	-	-	350.0	-13600	400.0	5334
)	450.0	6870	450.0	7300	-	-	450.0	400	-	-
	-	-	90.0	18800	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-
	-	-	328.6	4250	328.6	7500	-	-	-	-
	-	-	351.4	-460	351.4	9300	-	-	-	-
	-	-	-	-	-	-	-	-	-	-
	-	-	340.0	56810	339.0	17470	-	-	-	-
)	274.5	43000	274.5	17000	274.5	-19272	274.5	8600	274.5	30714
)	239.8	-3000	239.8	15000	-	-	239.8	45400	238.3	4054
b)	Sta (in.)	Load (in. -lb)	Sta (in.)	Load (in. -lb)	Sta (in.)	Load (in. -lb)	Sta (in.)	Load (in. -lb)	Sta (in.)	Load (in. -lb)
6)	90.0	$0.05(10^6)$	90.0	$0.011(10^6)$	-	-	90.0	$0.43(10^6)$	-	-
6)	450.0	$0.80(10^6)$	450.0	$0.08(10^6)$	-	-	450.0	$0.37(10^6)$	-	-

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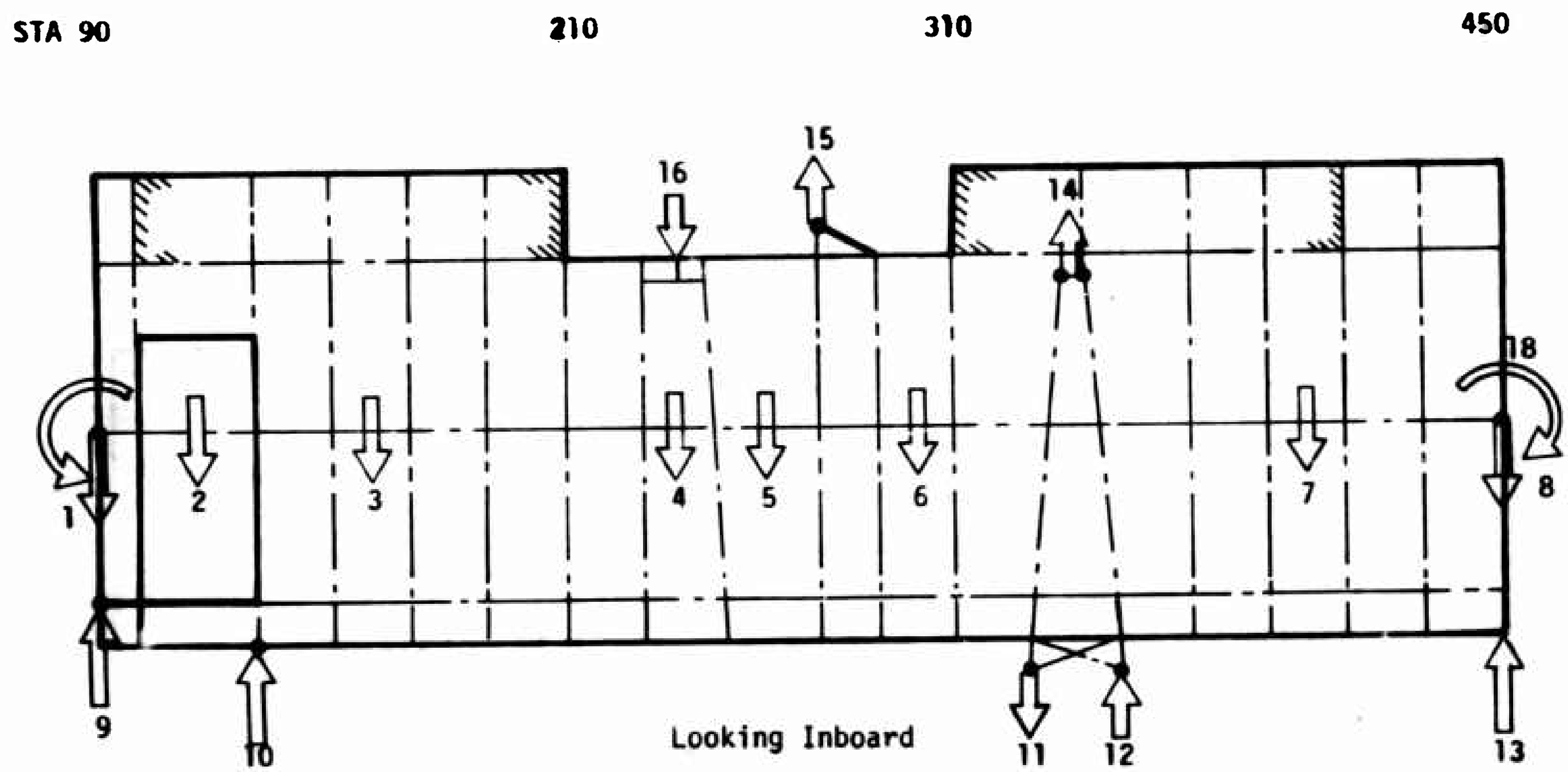


Figure 43. (U) Fuselage External Vertical Load Components.

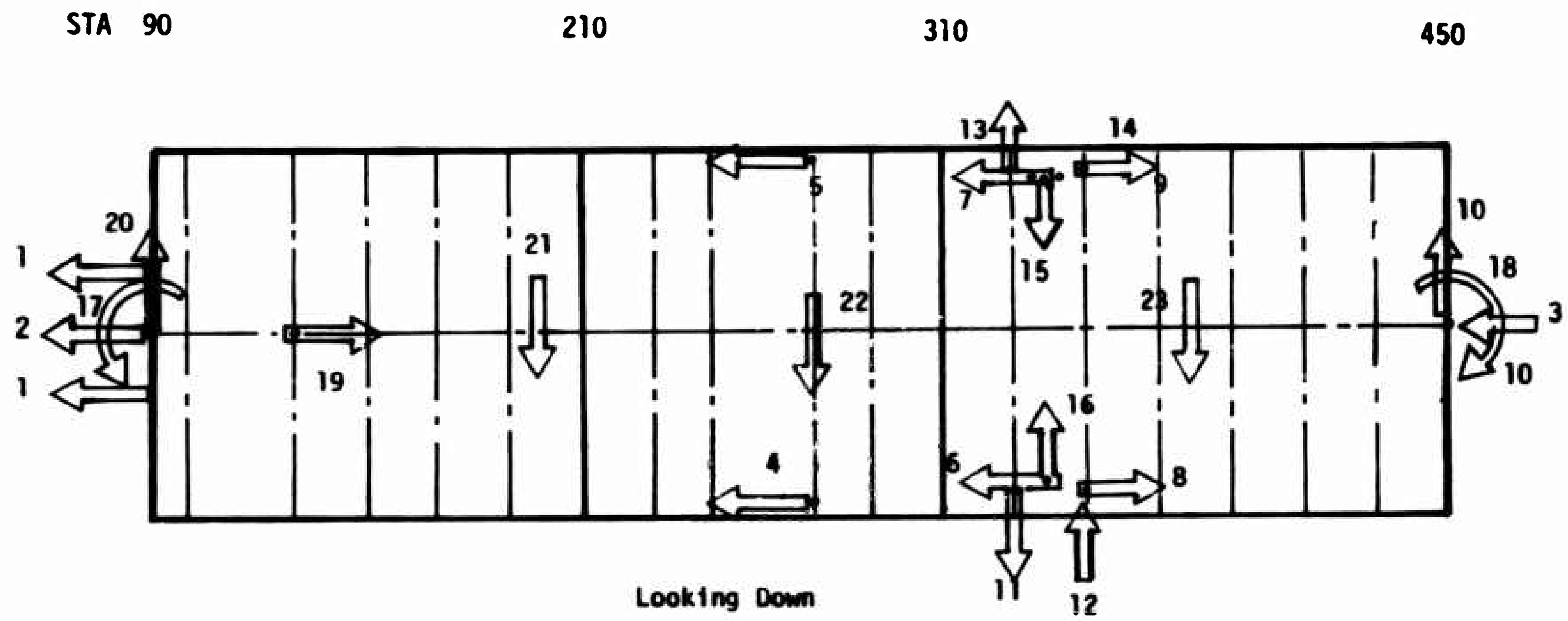


Figure 44. (U) Fuselage External Horizontal Load Components.

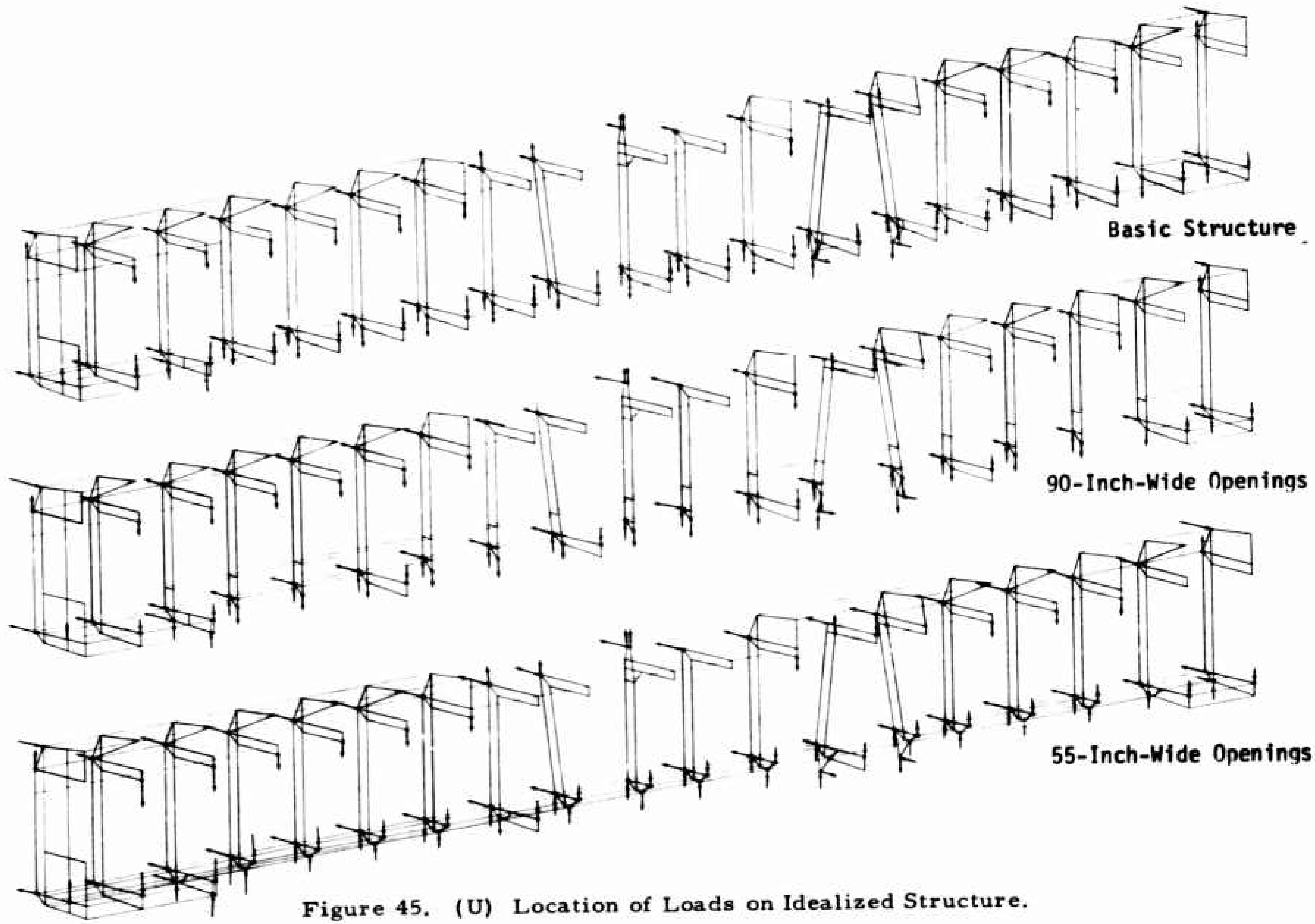


Figure 45. (U) Location of Loads on Idealized Structure.

Symmetrical Flight Gust Loads

The maximum vertical shears and positive bending moments in the fuselage are caused by the design gust loads.

The influence of wing bending restraint loads on the wing attachment frame has been included with this loading condition, which becomes the critical load for the frame and does not affect the basic shell structure analysis.

Anti-Symmetrical Flight Loads

The design loads for fuselage torque and side bending moments are obtained from the anti-symmetrical flight load. The critical structure loads occur aft of the wing attachment frame.

Out-of-Phase Main Landing Gear Loads

The three-point STOL landing condition is revised to impart the main landing gear spin-up load to one side of the fuselage and the spring-back load to the other side. The resultant shears on the structure between the landing gear attach frames determine structural member sizes.

Main Gear Striking an Obstruction

The design loads for the main landing gear attachment frames are obtained when one gear strikes an obstruction during a VTOL approach. The gear is assumed to be forced outboard as it contacts the obstruction.

Symmetrical Inverted Flight Gust Load

The wing actuating system and supporting structure are designed by the inverted flight gust loads.

Unit Torque Load on Fuselage

A 400-pound-per-inch torque load is applied to the fuselage shell structure to determine the torsional spring rate of the three idealized structural arrangements.

Cargo Load on Unlatched Doors

When in flight, the cargo floor doors are assumed to be unlatched and holding the cargo in place due to some malfunction in the pallet release mechanism. This adds the door actuating system loads to the appropriate fuselage frames.

AIRFRAME WEIGHT COMPARISON

The effect on structural weight due to alterations on the basic configuration was determined by a parametric study wherein the weight of the basic

structure was compared to the weight of the revised configurations. To produce a qualitative analysis, the weights of all three configurations were computed as idealized structural arrangements.

The structural idealization was accomplished on three configurations: the basic airframe, the double-row 10-exit, and the single-row 6-exit. The complete complement of fuselage frames, longerons, and skin panels was included in all three idealizations (Figure 46). The lower skin panels between Stations 130 and 430 were not included, as they were considered nonstructural for all analyses reported in Reference 95. By the same reasoning, the skin panels below the forward bay fuel tank were not considered. The cargo floor longitudinal stiffeners were omitted to minimize the number of structural items in the idealization.

The idealization was used as input data for an "Automated Structural Design" computer program. This program computes the sizes of each member to a predetermined stress level for the most critical load applied to it from as many loading conditions as are applied to the structure. The loads may be symmetrical or anti-symmetrical to the airframe reference axis. The program computes the deflections of as many points as requested by the input data.

Included in the computer output data is the calculated load in every member for each loading condition. The most critical load for each member is then printed out with the corresponding stress level, area, weight and margin of safety. The total structural weight is a summation of the maximum weight of each member based on all load conditions.

The weight of each structural bar and panel is printed out two ways: (1) individually, and (2) by a running total beginning with the first bar. To make the weight comparison, the output data was tabulated for each frame and each skin panel, longeron and cargo floor panel between each frame. These component weights were then listed in weight summary tables for the idealized basic structure and the idealized structure with the maximum number of cutouts. The individual component weights for the idealized structures having a smaller number of cutouts were estimated by two methods. The first method was to apportion equally any weight differential the component had between the basic and the minimum cutout structure and to apply this to the component's basic weight in all the structural configurations under consideration in this study. This was accomplished only if the component in question was not adjacent to a cutout. The second method was to ascertain the function of the component in each of the parametric configurations and then to estimate its weight relative to that calculated for the basic and/or maximum cutout structure analysis.

Structural Weight for a Double Row of Pallets

The weight of each idealized frame for the 90-inch-wide openings in the cargo floor and the lower surface of the fuselage is tabulated in Table X. The weights of the idealized frames for the basic airframe structure are included.

The estimated weights for all the fuselage frames in the two-, three- and four-cutout configurations are also listed. The summation of the calculated weights for the idealized basic structure frames is 984 pounds. This summation compares to the weight of 1119 pounds listed for the actual aircraft in Reference 19.

The summary of all the fuselage skin panel weights is noted in Table XI for all the idealized structural arrangements of the double-row configuration; all panels between adjacent frames are included in each weight value. The total fuselage skin panel weight for the basic configuration is 394 pounds compared to the 540-pound weight of the actual airframe in Reference 19. This weight differential represents the amount of stiffening material in the actual airframe that is not included in the parametric study.

The weights of the fuselage longerons and longitudinal stiffeners are noted in Table XII. The number entered in the table represents the weight of all longitudinal members located in the area under consideration for the idealized basic structure and all configurations of the 90-inch-wide cutout. The total weight calculated for the idealized basic structure is 127 pounds; the actual weight is 183 pounds as taken from the weight control book, Reference 19.

The weight of the idealized cargo floor not removed by the various cutout configurations is summarized in Table XIII. The individual weights listed represent those of the cargo floor skin panel and the cap material required to complete the idealized structure for the analysis. The total weight of the idealized basic cargo floor skin panel and the required longitudinal member for structural integrity is 139 pounds. The calculated weight for the actual airframe longitudinally stiffened cargo floor skin panel is 366 pounds; the actual weight does not include that of the cargo tiedown fittings, seat rail studs, and support structure. These members were considered as non-structural weight items in this study.

The weight of each idealized 45 x 55 exit door installation is summarized in Table XIV. The weight of the cargo floor skin and stiffeners is that of the referenced actual structure. The weight of the floor support structure is based on the required strength to support the 300-pound-per-square-foot loading.

The weights of all structural items under consideration are summarized in Table XV, for all the 90-inch-wide cutout configurations. An additional weight equal to 8.5 percent of the structural weight was included to account for fasteners and overlapping material. The total weight of the fuselage center section also includes the weight of the cargo floor exit door installations.

Two methods of indicating the effects on the structural weight of an aircraft due to various numbers of 55-inch full width cutouts through the

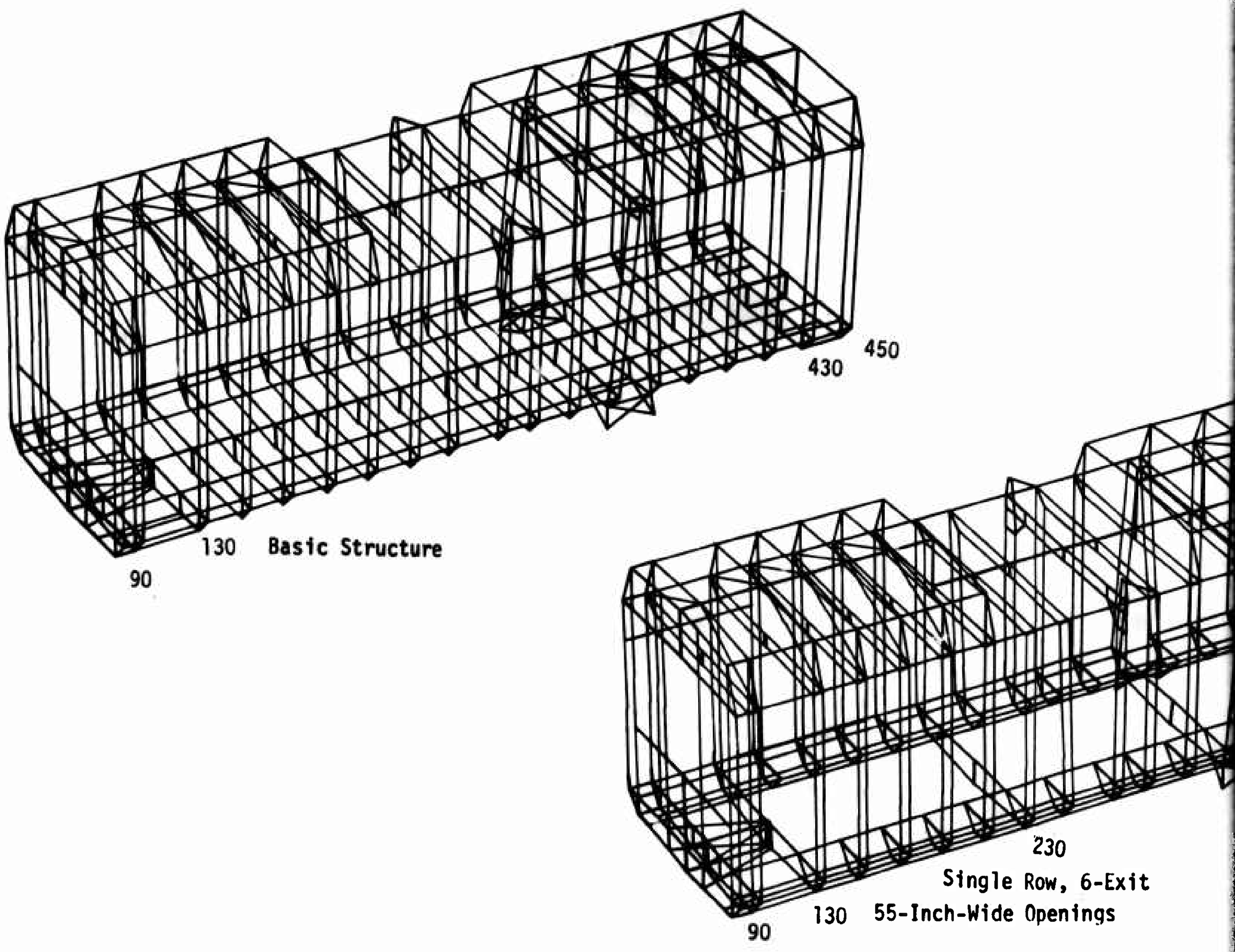
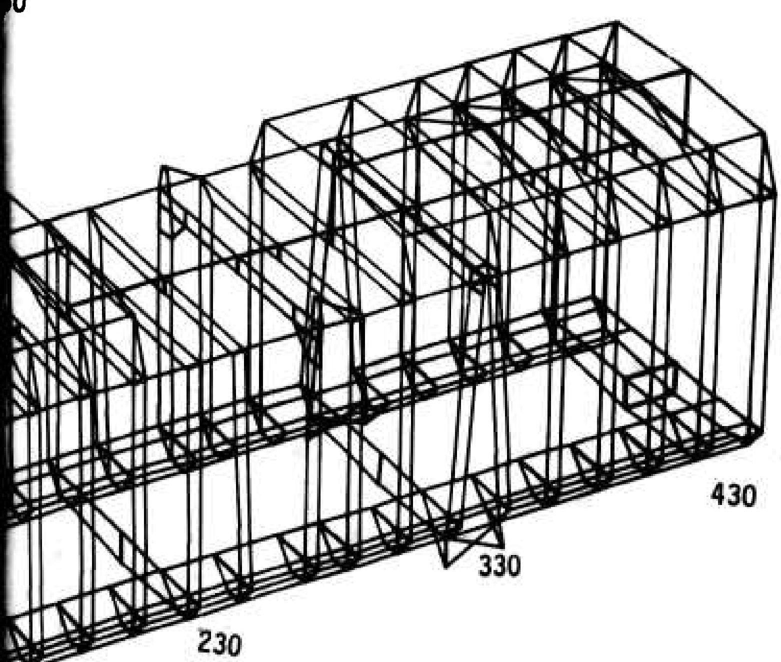
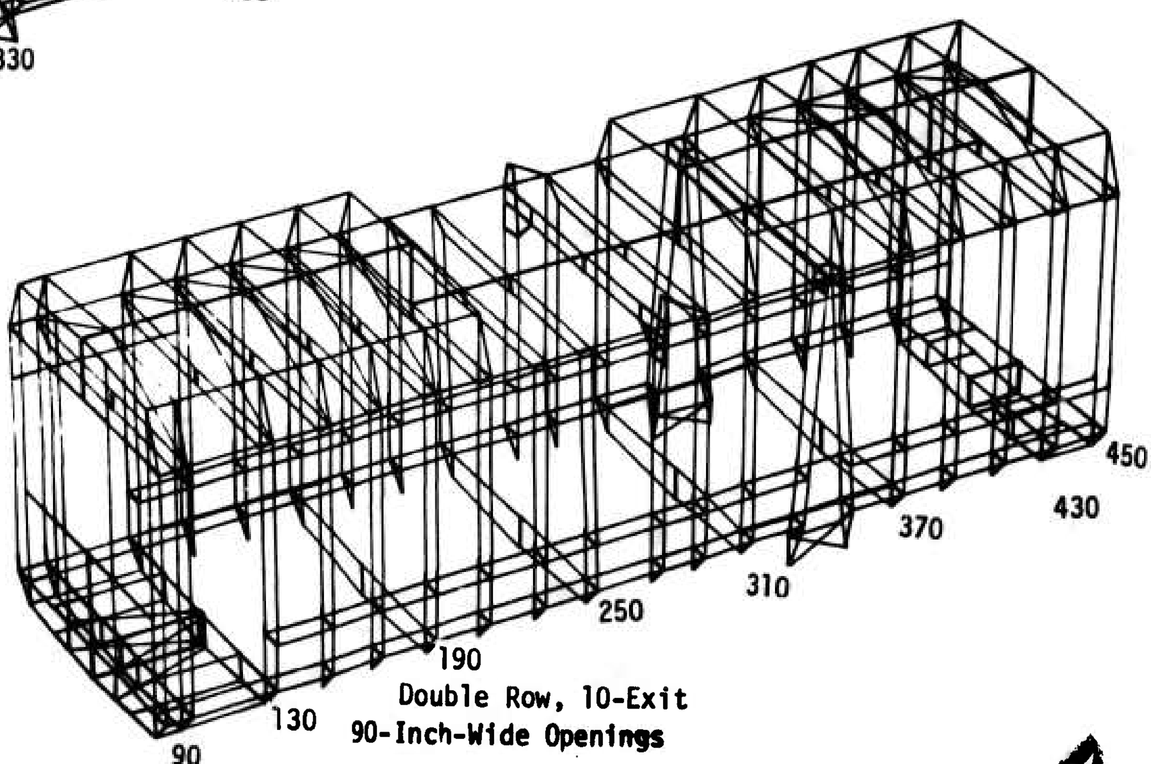


Figure 46. (U) Idealized Structural Arrangements, Automated Structural Design.



Single Row, 6-Exit
5-Inch-Wide Openings



Double Row, 10-Exit
90-Inch-Wide Openings

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TABLE (U)
WEIGHT SUMMARY – IDEALIZED STRUCTURE FRAME
(90-INCH OPENING)

Fuselage Frame Station (in.)	Structural Configuration				
	Basic Struct Weight (lb)	4-Door Struct Weight (lb)	6-Door Struct Weight (lb)	8-Door Struct Weight (lb)	10-Door Struct Weight (lb)
90	54.08	54.50	54.91	55.32	55.32
100	47.30	48.23	49.16	50.10	50.10
130	49.96	50.66	51.37	52.04	52.04
150	48.90	48.90	46.36	34.44	34.44
170	46.30	46.30	50.64	35.14	35.14
190	48.32	53.80	36.40	53.80	53.80
210	49.00	39.10	39.10	39.10	39.10
230	39.92	29.22	45.82	29.22	29.22
250	40.90	48.28	29.62	48.28	48.28
274.5	82.00	54.78	54.78	54.78	54.78
290	39.44	30.06	47.08	30.06	30.06
310	50.78	57.28	54.04	85.44	85.44
330	70.58	70.58	73.64	73.64	73.64
350	74.58	74.58	80.08	91.82	91.82
370	45.90	45.90	50.00	55.71	62.78
390	46.18	46.18	46.34	46.50	35.06
410	49.60	49.60	49.60	49.60	38.68
430	47.18	47.18	47.18	50.20	53.22
450	53.50	53.50	53.50	52.68	51.86
Total Weight	984.42	948.63	959.62	987.87	974.78

TABLE XI (U)
WEIGHT SUMMARY – IDEALIZED STRUCTURE SKIN PANEL
(90-INCH OPENING)

Location of Forward and Aft Ends Fus Frame Stations	Structural Configuration				
	Basic Struct Weight (lb)	4-Door Struct Weight (lb)	6-Door Struct Weight (lb)	8-Door Struct Weight (lb)	10-Door Struct Weight (lb)
Sta 90 – 130	44.72	48.14	51.56	54.98	54.98
130 – 150	20.08	19.88	19.75	19.50	19.50
150 – 170	20.12	19.82	19.52	19.24	19.24
170 – 190	20.08	19.81	19.54	19.28	19.28
190 – 210	20.12	19.86	19.60	19.34	19.08
210 – 230	18.76	18.66	18.56	18.46	18.36
230 – 250	17.16	17.16	17.16	17.16	17.16
250 – 274.5	23.92	24.44	24.96	25.48	26.00
274.5 – 290	15.36	15.65	15.94	15.23	16.52
290 – 310	18.80	19.25	19.70	20.15	20.60
310 – 330	33.14	55.62	78.10	78.10	78.10
330 – 350	17.10	21.73	26.36	26.36	26.36
350 – 370	31.16	31.16	50.15	50.15	69.14
370 – 390	25.40	25.40	28.64	31.88	35.12
390 – 410	25.40	25.40	25.40	28.10	30.80
410 – 430	20.12	20.12	20.12	22.96	25.80
430 – 450	22.32	22.32	22.32	25.62	28.92
Total Weight	393.76	424.42	477.38	491.99	524.96

TABLE XII (U)
WEIGHT SUMMARY – IDEALIZED STRUCTURE LONGERON
(90-INCH OPENING)

Location of Forward and Aft Ends Fus Frame Stations	Basic Struct Weight (lb)	Structural Configuration 4-Door Struct Weight (lb)	6-Door Struct Weight (lb)	8-Door Struct Weight (lb)	10-Door Struct Weight (lb)
Sta 90 – 130	23.10	29.44	35.78	42.12	42.12
130 – 150	6.44	10.70	14.96	19.22	19.22
150 – 170	5.42	8.97	12.53	16.08	16.08
170 – 190	5.30	8.27	11.24	14.22	14.22
190 – 210	5.54	9.06	12.58	12.58	12.58
210 – 230	5.28	10.16	10.16	10.16	10.16
230 – 250	5.08	8.22	8.22	8.22	8.22
250 – 274.5	8.34	12.10	12.10	12.10	12.10
274.5 – 290	7.10	9.84	9.84	9.84	9.84
290 – 310	5.44	7.38	9.30	9.30	9.30
310 – 330	9.42	23.00	50.18	50.8	50.18
330 – 350	8.34	18.96	37.92	75.84	75.84
350 – 370	7.50	7.50	21.04	34.58	48.12
370 – 390	6.00	6.00	8.37	10.74	13.10
390 – 410	6.00	6.00	6.00	9.06	12.12
410 – 430	5.20	5.20	5.20	8.79	15.98
430 – 450	7.76	7.76	7.76	10.13	14.86
Total Weight	127.26	188.56	273.18	353.16	384.04

TABLE XIII (U)
WEIGHT SUMMARY – IDEALIZED STRUCTURE CARGO FLOOR
(90-INCH OPENING)

Location of Forward and Aft Ends Fus Frame Stations	Structural Configuration				
	Basic Struct Weight (lb)	4-Door Struct Weight (lb)	6-Door Struct Weight (lb)	8-Door Struct Weight (lb)	10-Door Struct Weight (lb)
Sta 90 – 130	17.58	17.67	17.76	17.84	17.84
130 – 150	7.36	7.36	7.36	–	–
150 – 170	7.36	7.36	7.36	–	–
170 – 190	7.36	7.36	–	–	–
190 – 210	7.36	–	–	–	–
210 – 230	7.36	–	–	–	–
230 – 250	7.36	–	–	–	–
250 – 274.5	9.00	–	–	–	–
274.5 – 290	5.64	–	–	–	–
290 – 310	7.36	–	–	–	–
310 – 330	7.52	7.52	–	–	–
330 – 350	10.64	10.64	–	–	–
350 – 370	7.44	7.44	7.44	–	–
370 – 390	7.36	7.36	7.36	7.36	–
390 – 410	7.36	7.36	7.36	7.36	–
410 – 430	7.36	7.36	7.36	7.36	–
430 – 450	7.36	7.36	7.36	7.36	7.36
Total Weight	138.78	94.79	69.36	47.28	25.20

TABLE XIV (U)
WEIGHT SUMMARY – CARGO FLOOR AIRDROP EXIT DOOR

Name of Component	45- x 55-Inch Opening: Door Component Weight for System I or II	45- x 55-Inch Opening: Door Component Weight for System III	27.5- x 75-Inch Opening: Door Component Weight for System I or II
Floor Structure	38.6	34.9	40.5
Outer Skin Structure	10.0	10.0	10.5
Bulkhead & Ribs	12.1	21.3	15.0
Hinge Fitting	3.5	3.5	6.0
Door Seals & Access Cover	3.0	3.0	3.0
Joints & Fastener	6.8	7.3	7.5
Door Assembly	74.0	80.0	82.5
Door Latches & Actuation	31.5	31.5	31.5
Hydraulic Control System	5.0	5.0	5.0
Electrical Control System	1.5	1.5	1.5
Door Installation Weight	112.0	[illegible]	120.5

TABLE XV (U)
STRUCTURAL WEIGHT SUMMARY – 90-INCH-WIDE OPENINGS IN FUSELAGE

		Structural Configuration									
		Basic		4-Door		6-Door		8-Door		10-Door	
Name of Component	Actual* Weight (lb)	** (lb)	*** (lb)	** (lb)	*** (lb)	** (lb)	*** (lb)	** (lb)	*** (lb)	** (lb)	*** (lb)
Frames & Bulkheads	1119	984	1119	949	1079	960	1092	988	1124	975	1109
Skin Panels	540	394	540	424	570	477	623	492	638	525	671
Stiffeners & Longerons	183	127	183	189	245	273	329	353	409	384	440
Cargo Floor	366	139	366	95	237	69	169	47	105	25	39
Joints & Fastener	188	140	188	140	188	140	188	140	188	140	188
Center Section Structural Weight	2396	1784	2396	1797	2319	1919	2401	2020	2464	2049	2447
Basic Door Installation (Excluding Cargo System)	0	0	0		472		708		944		1180
Total Center Section Weight (Excluding Cargo System III)	2396		2396		2791		3109		3408		3627

* Obtained from Reference 19
** Idealized structural weight obtained from the computer output data
*** Weight of structure as correlated to the actual weight

cargo floor and the fuselage lower surface are presented. The first method is a plot of the effect on the fuselage center section structural weight due to various lengths of full width (90-inch) cargo floor cutouts and is shown in Figure 47. The percent increase to the structural weight is noted for the various configurations that were under study. The second method is a chart of the effects on the operator's weight empty of the aircraft due to the cutouts. The percent increase for the OWE is noted in Figure 48, for various lengths of full width (90-inch) cutouts. The percent increase is shown for each of the cargo airdrop exit configurations.

Structural Weight for a Single Row of Pallets

A comprehensive analysis was made to determine the effects on the weight of the fuselage center section structure due to various numbers of 55-inch-wide by 95-inch-long exit doors cut through the cargo floor and lower surface. The output from the computer was used to determine the structural weight of the idealized configuration having the maximum number of cutouts. The same methods used to estimate the weights for the intermediate configurations of the full width (90-inch) cutouts were employed for the 55-inch-wide cutouts.

The weight summaries for the fuselage frames, skin panels, longerons and remaining cargo floor panels are presented in Tables XVI through XVIII.

The weight for the full depth and full strength cargo floor exit door as presented in Table XIX is a summation of the weights of the various components under consideration.

The effects on the structural weight of the basic idealized structure for the one-, two-, and three-cutout configurations are summarized in Table XX.

The percent increase in structural weight for the fuselage center section is shown on Figure 47 for various numbers of airdrop exit provisions.

The effects on the operator's weight empty of the aircraft due to the configuration changes are shown on Figure 48.

AIRFRAME STRUCTURAL STIFFNESS COMPARISON

The torsional stiffness of the basic fuselage center section structure will be reduced by the cutouts through the cargo floor and lower surfaces. To produce a qualitative comparison of the effects the cutouts have on the structural integrity of the fuselage, it was necessary to compute the unit length angle of twist due to a unit torque for the three idealized configurations.

The torsional parameter, GJ, was determined for the idealized structural arrangements for the basic aircraft, the 90-inch-wide cutouts and the 55-inch-wide cutouts. The maximum number of cutouts in each of the alternate configurations were considered for the analysis.

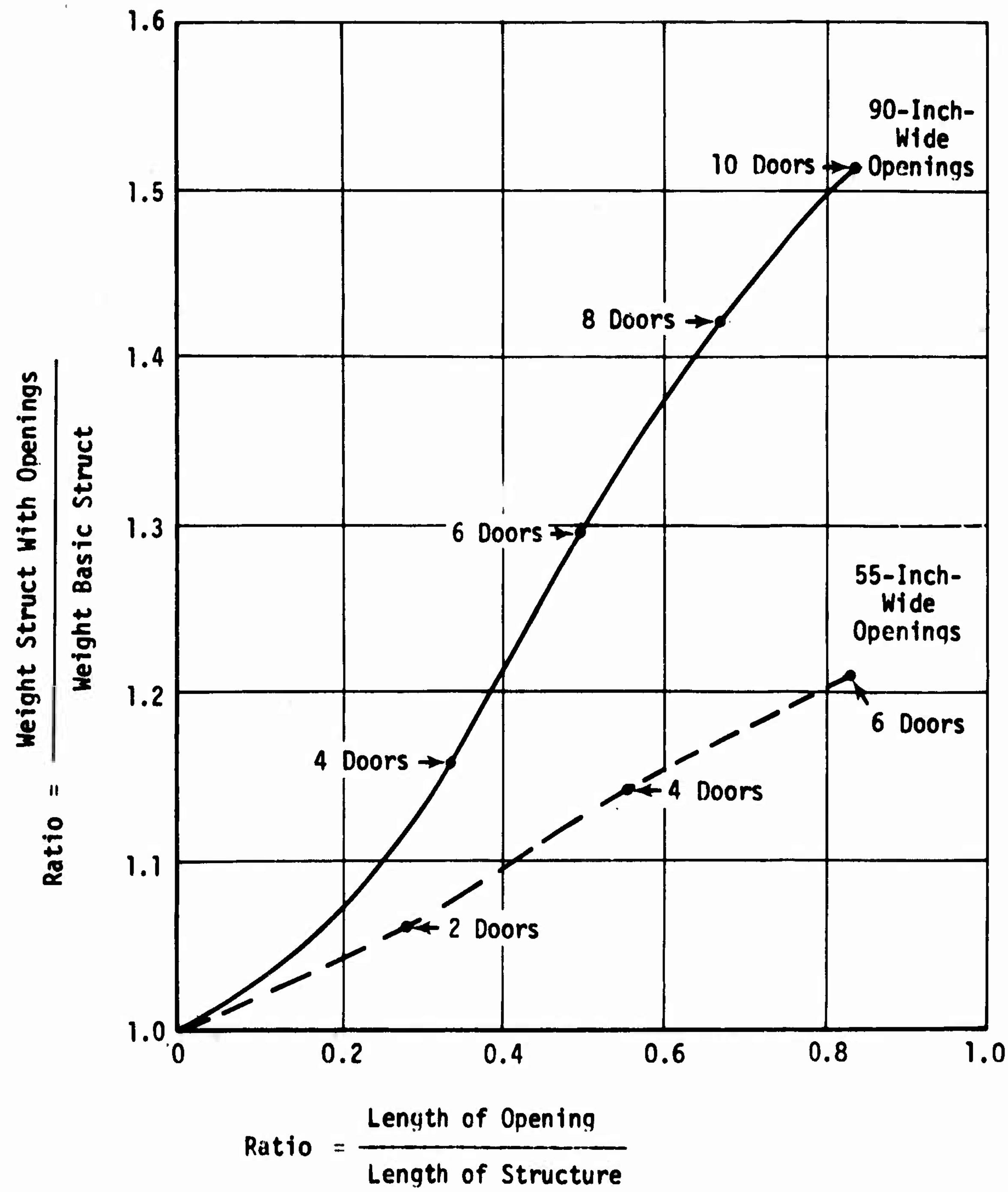


Figure 47. (U) Effect on Structural Weight Due to Various Cargo Floor Opening Lengths.

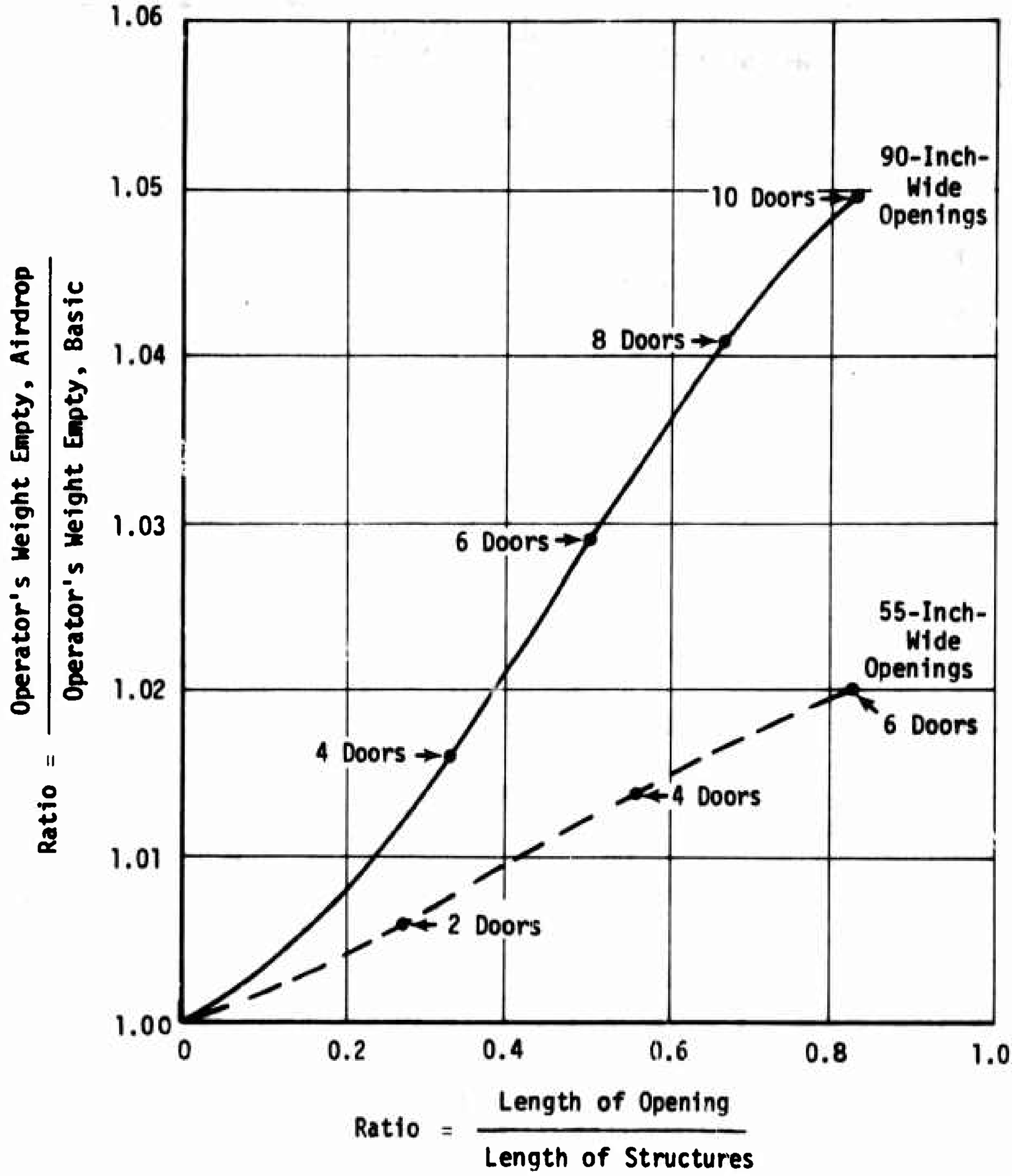


Figure 48. (U) Effect on Operator's Weight Empty (OWE) Due to Various Cargo Floor Opening Lengths.

TABLE XVI (U)
WEIGHT SUMMARY — IDEALIZED STRUCTURE FRAME
(55-INCH OPENING)

Fuselage Frame Station	Structural Configuration: Basic Struct Weight (lb)	2-Door Struct Weight (lb)	4-Door Struct Weight (lb)	6-Door Struct Weight (lb)
90	54.08	54.33	54.58	54.86
100	47.30	47.30	47.32	47.34
130	49.96	49.96	50.18	50.40
150	48.90	48.90	48.90	41.10
170	46.30	46.30	38.14	38.14
190	48.32	48.32	33.94	33.94
210	49.00	49.00	41.72	41.72
230	39.92	39.92	39.92	46.40
250	40.90	32.56	40.90	32.56
274.5	82.00	65.00	70.00	60.24
290	39.44	31.12	31.12	31.12
310	50.78	50.78	42.34	42.34
330	70.58	70.58	68.53	66.52
350	74.58	74.58	67.50	60.64
370	45.90	45.90	45.90	37.54
390	46.18	46.18	46.18	32.02
410	49.60	49.60	49.60	41.44
430	47.18	49.31	51.44	53.58
450	53.50	54.35	55.20	56.04
Total Weight	984.42	953.99	923.41	867.94

TABLE XVII (U)
WEIGHT SUMMARY — IDEALIZED STRUCTURE SKIN PANEL
(55-INCH OPENING)

Location of Forward and Aft Ends Fus Frame Stations	Structural Configuration			
	Basic Struct Weight (lb)	2-Door Struct Weight (lb)	4-Door Struct Weight (lb)	6-Door Struct Weight (lb)
90 — 130	44.72	44.72	49.32	49.32
130 — 150	20.08	20.08	13.28	13.28
150 — 170	20.12	20.12	21.24	21.24
170 — 190	20.08	20.08	19.92	19.92
190 — 210	20.12	20.12	19.92	19.92
210 — 230	18.76	18.60	18.60	18.60
230 — 250	17.16	16.96	16.96	16.96
250 — 274.5	23.92	24.11	24.30	24.48
274.5 — 290	15.36	15.08	14.80	14.52
290 — 310	18.80	18.74	18.67	18.60
310 — 330	33.14	33.14	32.74	32.74
330 — 350	17.10	17.10	23.45	29.80
350 — 370	31.16	31.16	31.16	30.86
370 — 390	25.40	25.34	25.27	25.20
390 — 410	25.40	25.40	24.04	24.04
410 — 430	20.12	20.12	20.12	18.76
430 — 450	22.32	22.51	22.70	22.88
Total Weight	393.76	393.38	396.49	401.12

TABLE XVIII (U)
WEIGHT SUMMARY – IDEALIZED STRUCTURE LONGERON
(55-INCH OPENING)

Location of Forward and Aft Ends Fus Frame Stations	Structural Configuration			
	Basic Struct Weight (lb)	2-Door Struct Weight (lb)	4-Door Struct Weight (lb)	6-Door Struct Weight (lb)
Sta 90 — 130	23.10	24.10	25.11	26.12
130 — 150	6.44	6.50	7.74	8.98
150 — 170	5.42	5.50	7.06	8.62
170 — 190	5.30	5.40	8.22	8.22
190 — 210	5.54	6.91	8.28	8.28
210 — 230	5.28	6.08	6.88	7.68
230 — 250	5.08	5.81	6.54	7.26
250 — 274.5	8.34	9.23	10.12	11.02
274.5 — 290	7.10	7.64	8.18	8.72
290 — 310	5.44	6.04	6.64	7.24
310 — 330	9.42	10.41	11.40	11.40
330 — 350	8.34	8.41	8.48	8.48
350 — 370	7.50	7.50	8.91	10.32
370 — 390	6.00	6.75	7.50	8.26
390 — 410	6.00	6.88	7.76	8.64
410 — 430	5.20	5.20	7.22	9.24
430 — 450	7.76	7.76	8.08	8.40
Total Weight	127.26	136.12	154.12	166.88

TABLE XIX (U)
WEIGHT SUMMARY – IDEALIZED STRUCTURE CARGO FLOOR
(55-INCH OPENING)

Location of Forward and Aft Ends Fus Frame Stations	Structural Configuration			
	Basic Struct Weight (lb)	2-Door Struct Weight (lb)	4-Door Struct Weight (lb)	6-Door Struct Weight (lb)
Sta 90 — 130	17.58	19.97	22.35	24.74
130 — 150	7.36	7.36	7.36	6.88
150 — 170	7.36	7.36	6.18	6.18
170 — 190	7.36	6.37	5.38	5.38
190 — 210	7.36	4.56	4.56	4.56
210 — 230	7.36	3.82	3.82	3.82
230 — 250	7.36	3.18	3.18	3.18
250 — 274.5	9.00	3.32	3.32	3.32
274.5 — 290	5.64	2.12	2.12	2.12
290 — 310	7.36	3.02	3.02	3.02
310 — 330	7.52	7.52	3.80	3.80
330 — 350	10.64	10.64	6.22	6.22
350 — 370	7.44	7.44	7.44	5.14
370 — 390	7.36	7.36	7.36	4.88
390 — 410	7.36	7.36	7.36	5.58
410 — 430	7.36	7.36	7.36	6.40
430 — 450	7.36	7.36	11.42	15.48
Total Weight	138.78	116.12	112.25	110.70

TABLE XX (U)
STRUCTURAL WEIGHT SUMMARY – 55-INCH-WIDE OPENINGS IN FUSELAGE

		Structural Configuration							
		Basic		2-Door		4-Door		6-Door	
Name of Component	Actual* Weight (lb)	** (lb)	*** (lb)	** (lb)	*** (lb)	** (lb)	*** (lb)	** (lb)	*** (lb)
Frames & Bulkhead	1119	984	1119	954	1089	923	1058	868	1003
Skin Panels	540	394	540	393	539	396	542	401	547
Stiffener & Longerons	183	127	183	136	192	154	210	167	223
Cargo Floor	366	139	366	116	300	112	252	111	209
Joints & Fastener	188	140	188	140	188	140	188	140	188
	2396	1784	2396	1739	2308	1725	2250	1687	2170
Basic Door Installation (Excluding Cargo System)	0	0	0		241		482		723
Total Center Section Weight (Excluding Cargo System)	2396		2396		2549		2732		2893

* Obtained from Reference 19
** Idealized structural weight obtained from the computer output data
*** Weight of structure as correlated to the actual weight

The magnitude of the three torsional stiffness parameters is shown in Figure 49. The torsional stiffness of the structure with full width (90-inch) cutouts is considerably less than that of the basic airframe. Should this value be less than the minimum stiffness requirements, additional horizontal keel box area would have to be added to the lower surface. This would either increase the total width of the fuselage or reduce the width of cutout permitted through the cargo floor and lower surface.

DESCRIPTION OF FINAL CONFIGURATION

The configuration selected as the most feasible to provide for airdrop of palletized cargo through the floor of an aircraft fuselage is the double-row arrangement having eight exit doors. The locations of the cargo floor and fuselage lower surface cutouts are shown on Figure 50.

The full depth exit doors are supported by hinge fittings at four locations and actuated by a hydraulic rotary actuator mounted to the keel box structure as shown in View A-A of Figure 50. The method of attaching the hinge fitting to the actuator for ease of door removal is illustrated in Section B-B of Figure 50. The curved panels shown are actuated by a linkage system connected to the door structure and may be independently opened for access to the actuators while the exit door is closed.

The fuselage frame (lateral floor beam) located between sets of doors is shown in Section C-C of Figure 50. The lower beam is an extruded aluminum fitting mounted to the fuselage frame with tension bolts. This configuration will provide for a quick service change should the beam become damaged. The relative positions of door latch fittings, guide rollers and sealing provisions are shown in Section E-E of Figure 50.

The installation of a nylon webbing cargo barrier net is shown in Section D-D of Figure 50. The net is located at Station 130 to preserve the entrance and emergency escape provisions.

The relative location of the cargo handling equipment necessary for the airdrop system is shown on the cargo floor plan view of Figure 50.

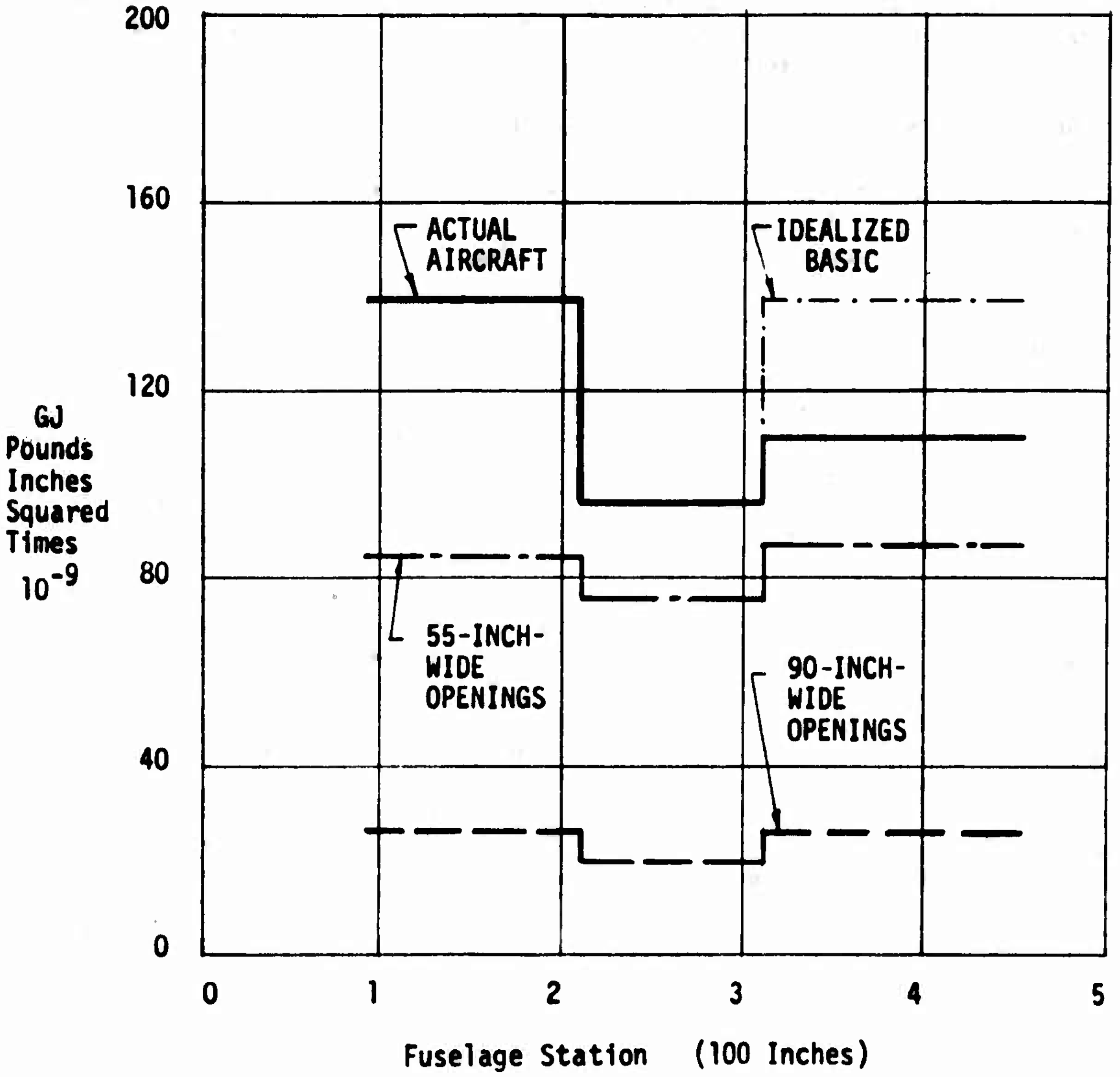


Figure 49. (U) Fuselage Torsional Stiffness Comparison.

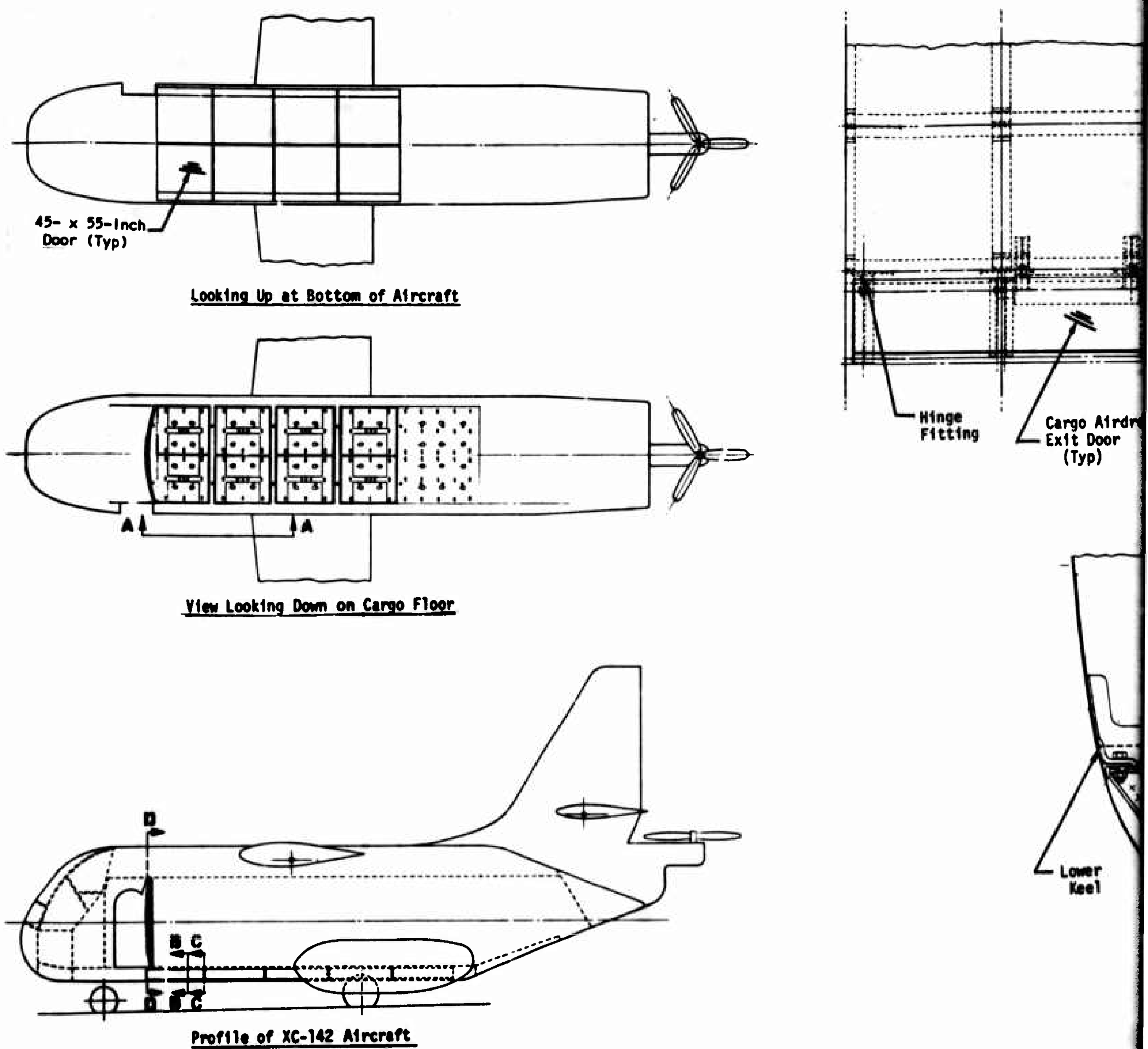
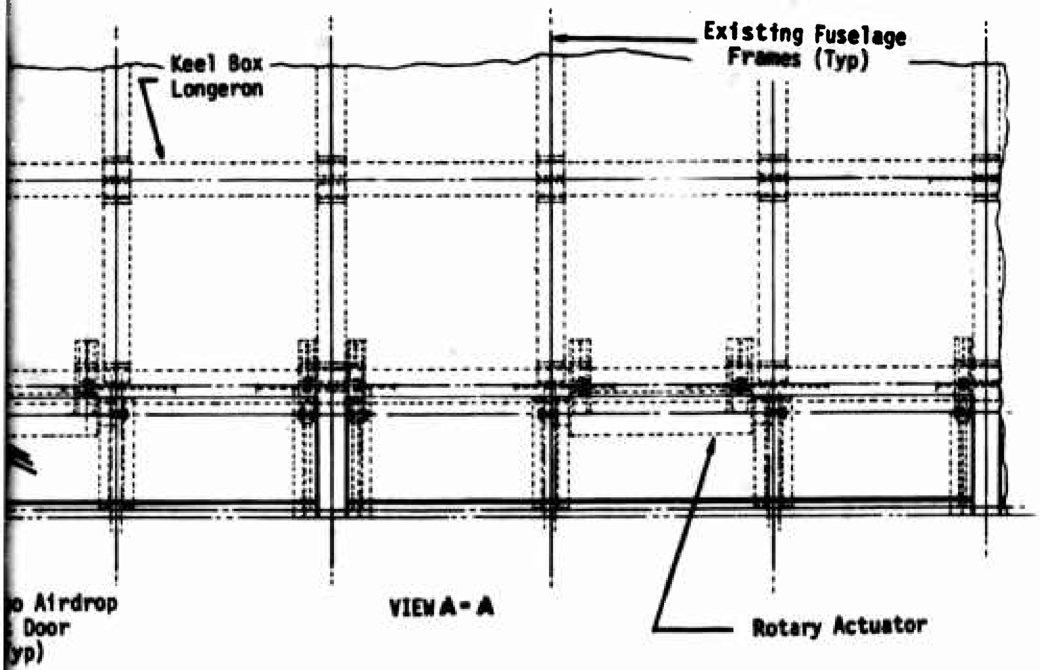
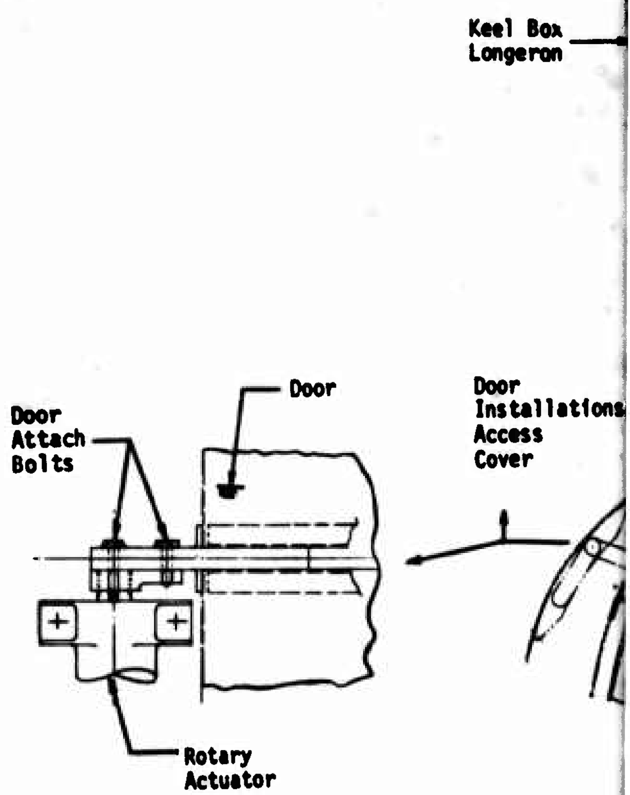
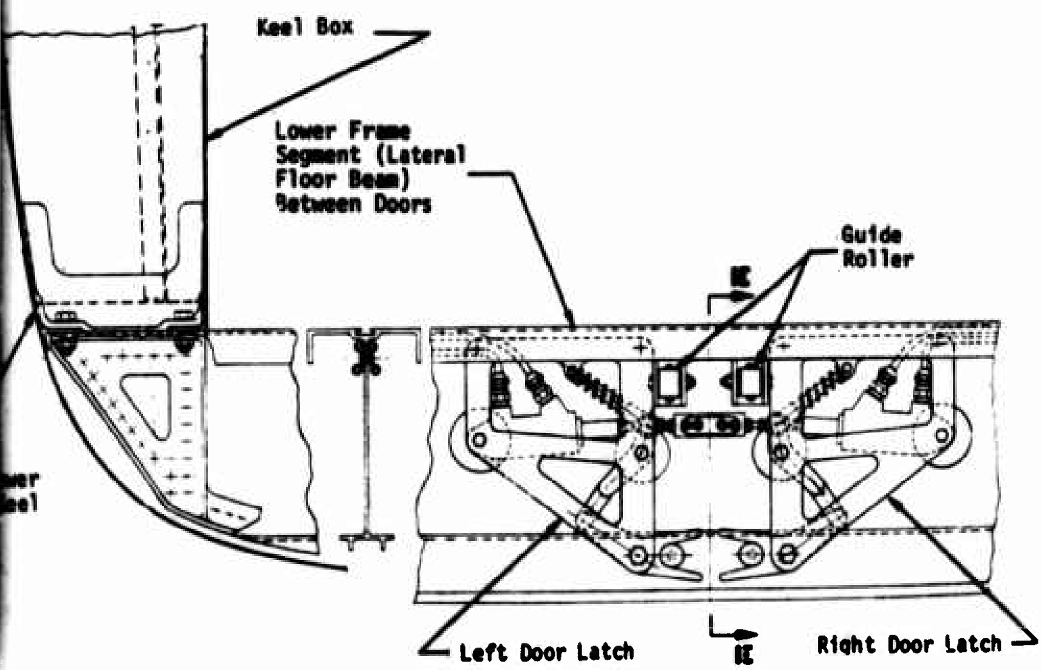


Figure 50. (U) Structural Arrangement – Eight 45- x 55-Inch Openings.

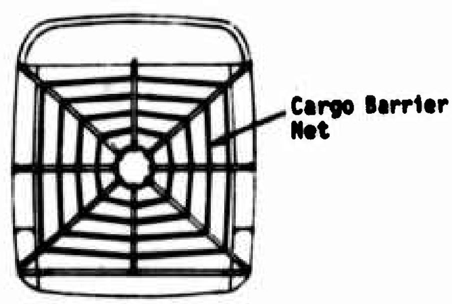


VIEW A-A



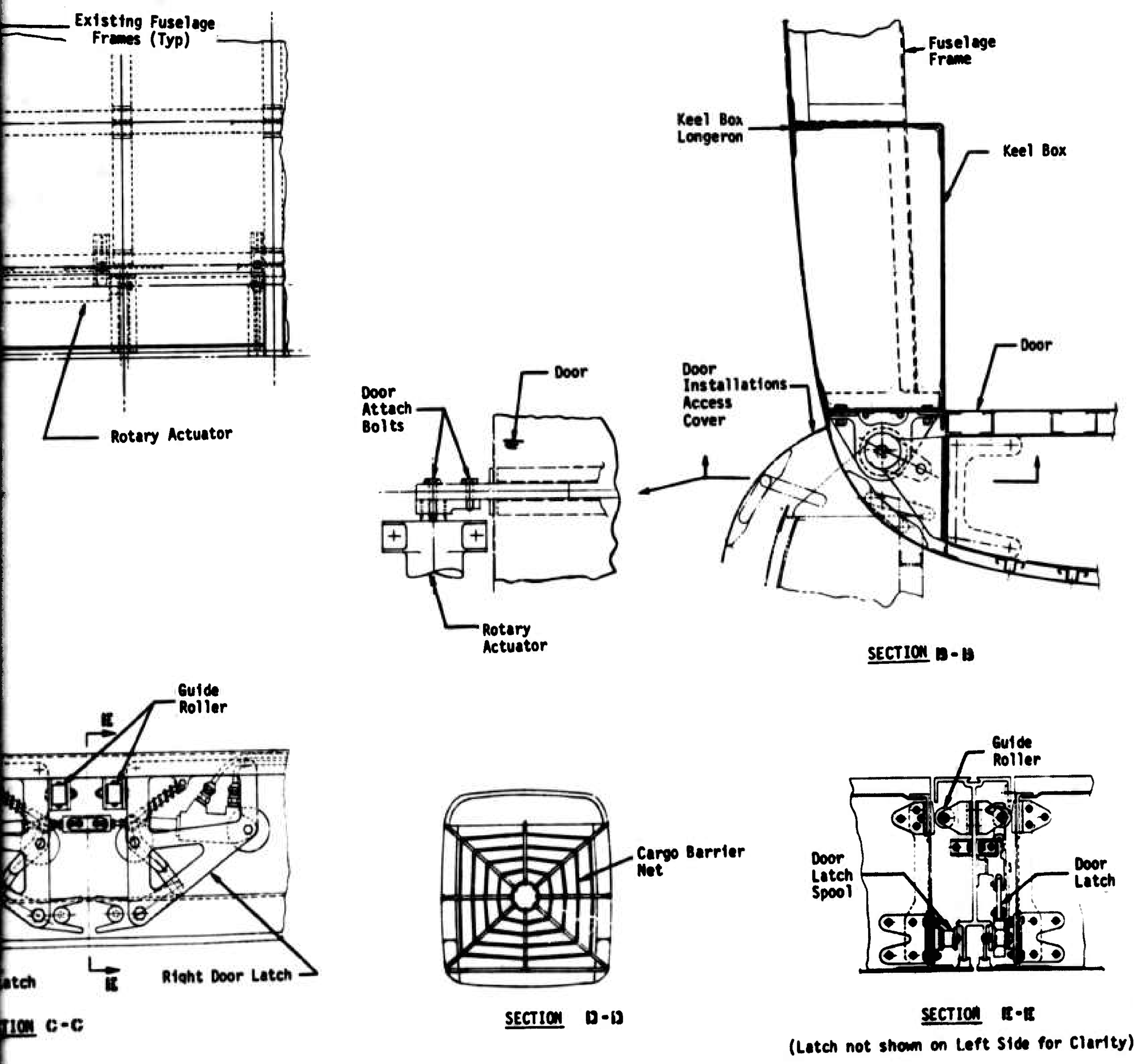


SECTION C-C



SECTION D-D

2


Existing Fuselage Frames (Typ)
Rotary Actuator
Door
Door Attach Bolts
Rotary Actuator
Fuselage Frame
Keel Box Longeron
Keel Box
Door
Door Installations Access Cover
SECTION B-B
Guide Roller
E
Right Door Latch
atch
E
TION C-C
Cargo Barrier Net
SECTION D-D
Guide Roller
Door Latch Spool
Door Latch
SECTION E-E
(Latch not shown on Left Side for Clarity)

3

(U) STABILITY AND CONTROL ANALYSIS

The purpose of this analysis is to determine the response of an aircraft equipped with a vertical/modular and a conventional aerial-delivery system following the release of cargo. The XC-142A aircraft was used as the delivery vehicle in these studies since its aerodynamic, mass, and inertial characteristics were readily available. Analog and digital computers were employed to solve the equations of motion and to generate time histories of the aircraft response.

Time histories of the aircraft response following the release of various cargo weights from several locations in the cargo compartment were obtained with the aircraft in the hover, transitional, and conventional flight modes for the vertical/modular, aerial-delivery system. Time histories were also obtained of the aircraft response during and after the sequential drop of several loads from the aircraft equipped with the conventional delivery system using the gravity drop method.

METHOD OF ANALYSIS

Loadings Investigated

Several cargo compartment arrangements as shown in Figures 30 through 33 have been studied from the structural and operational standpoints for the vertical/modular, aerial-delivery system. The arrangement shown in Figure 33 was selected for the stability and control analysis because it allows cargo to be released from the most forward and aft locations from the no-cargo center-of-gravity location. This arrangement has five compartments with longitudinal centers at fuselage stations 160, 220, 280, 340, and 400. The large number of cargo loading combinations possible with this arrangement could not all be investigated in this study. However, each compartment was loaded as the last remaining load aboard to the maximum weight allowed by the cargo loading envelope shown in Figure 51. Additional loads at fuselage stations 90 and 135 and overloads at stations 220 and 280 were studied. The aircraft response to the release of any one of these loads is greatest, since the aircraft mass and pitching-moment of inertia are least following the release of the load. The loads at fuselage stations 90 and 135 are hypothetical and were included to determine the effect of loads at the maximum possible distance from the no-cargo center of gravity. The compartments with centers at fuselage stations 160 and 220 and stations 90 and 135 were loaded to the forward center-of-gravity limit, and the compartments with centers at stations 280, 340, and 400 were loaded to the aft limit.

These loadings and the unbalanced lift and pitching moments due to their release from the vertical/modular system are shown in Tables XXI, XXII, and XXIII for the hover, transitional, and conventional flight modes, respectively.

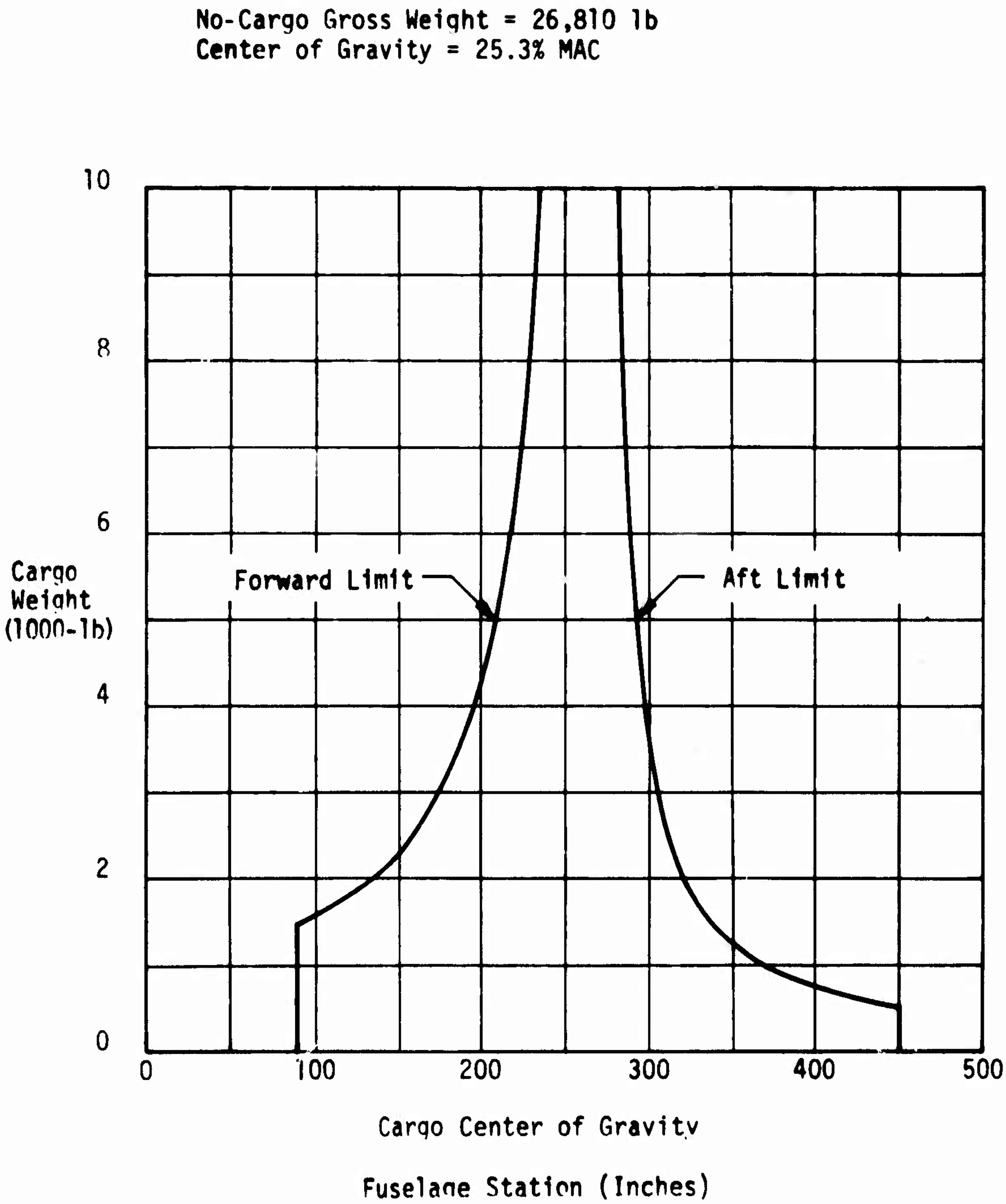


Figure 51. (U) Cargo Loading Envelope.

TABLE XXI (U)
AERODYNAMIC, MASS, AND INERTIA DATA FOR STABILITY AND CONTROL ANALYSIS IN HOVER MODE

Gr. Wt.	=	26,810 lb (after drop)
C. G.	=	25.4% MAC
m	=	832.6 slugs
I_Y	=	88,091 slug-ft^2
X_u	=	-22.0 lb-sec/ft
M_u	=	1760.0 lb-sec
Z_w	=	-1044.0 lb-sec/ft
M_w	=	-52.0 lb-sec
M_q	=	-573,400.0 ft-lb-sec/rad
M	=	-360,000 ft-lb/rad

Weight Dropped (lb)	Location of Weight (fus sta)*	Z_o (lb)	M_o (ft/lb)
1475	90	-1475	21,450
2000	135	-2000	21,820
2500	160	-2500	22,200
4000	220	-4000	23,400
6250	220	-6250	25,050
700	400	- 700	-7,800
1400	340	-1400	-5,600
4000	280	-4000	-6,950
5400	280	-5400	-9,210

*Fuselage station in inches

TABLE XXII (U)
AERODYNAMIC, MASS, AND INERTIA DATA FOR STABILITY AND CONTROL ANALYSIS IN TRANSITIONAL FLIGHT MODE

Gr. Wt.	= 26,810 lb (after drop)	T_u	= -64.0 lb-sec/ft
C.G.	= 25.4% MAC	C_{L_α}	= 4.8 per rad
m	= 832.6 slugs	$C_{L_{D_\alpha}}$	= 3.2 per rad
I_y	= 88,091 slug-ft^2	C_{L_q}	= 53.1 per rad
Altitude	= Sea Level	C_{D_α}	= 2.76 per rad
u_1	= 98.8 ft/sec	$C_{D_{D_\alpha}}$	= 0 per rad
ξ_T	= 8.0 deg	C_{D_q}	= 0 per rad
α_1	= -2.0 deg	C_{m_θ}	= -0.38 per rad
C_{L_1}	= 4.33	C_{m_α}	= 0 per rad
C_{D_1}	= 1.596	$C_{m_{D_\alpha}}$	= -9.84 per rad
C_{m_1}	= 0.1715	C_{m_q}	= -163.0 per rad

Weight Dropped (lb)	Location of Weight (fus sta)*	ΔC_L (-)	ΔC_m (-)
1475	90	0.238	0.468
2000	135	0.322	0.473
2500	160	0.403	0.485
4000	220	0.645	0.508
6250	220	1.010	0.543
700	400	0.113	-0.146
1400	340	0.226	-0.148
4000	280	0.645	-0.160
5400	280	0.871	-0.166

*Fuselage station in inches

TABLE XXIII (U)

AERODYNAMIC, MASS, AND INERTIA DATA FOR STABILITY AND CONTROL ANALYSIS IN CONVENTIONAL FLIGHT MODE

Gr. Wt.	= 26,810 lb (after drop)	T_u	= 0
C.G.	= 25.4% MAC	C_{L_α}	= 6.3 per rad
m	= 832.6 slugs	$C_{L_{D_\alpha}}$	= 2.38 per rad
Iy	= 88,091 slug-ft^2	C_{L_q}	= 7.32 per rad
Altitude	= Sea Level	C_{D_α}	= 0.66 per rad
u_1	= 202.7 ft/sec	$C_{D_{D_\alpha}}$	= 0 per rad
ϵ_T	= 0 deg	C_{D_q}	= 0 per rad
α_1	= 1.0 deg	C_{m_θ}	= 0 per rad
C_{L_1}	= 1.0277	C_{m_α}	= -0.756 per rad
C_{D_1}	= 0.129	$C_{m_{D_\alpha}}$	= -7.18 per rad
C_{m_1}	= 0.016	C_{m_q}	= -22.1 per rad

Weight Dropped (lb)	Location of Weight (fus sta)*	ΔC_L	ΔC_m
1475	90	0.0565	0.106
2000	135	0.0766	0.109
2500	160	0.0957	0.111
4000	220	0.1530	0.115
6250	220	0.240	0.125
700	400	0.0268	-0.07
1400	340	0.0536	-0.08
4000	280	0.153	-0.085
5400	280	0.207	-0.09

*Fuselage station in inches

The sequential drops of six and seven 2100-pound A-22 containers by the gravity drop method were investigated with the aircraft in the conventional flight mode with zero wing incidence and 30 degrees of flap deflection. The container discharge conditions for these drops were an aircraft fuselage angle of attack and pitch attitude of 5 degrees, a coefficient of friction between the load and cargo floor rollers of 0.025, and uniform acceleration of the containers. The variation of the aircraft mass, pitching-moment of inertia, and pitching moment with time following the release and discharge of the containers is shown in Figure 52.

Equations of Motion

The equations of motion for the hover mode analysis are linearized three-degree-of-freedom longitudinal equations as shown in Table XXIV. Since the servo characteristics of the stability augmentation system were unknown, the perfect servo or effective derivative method was used to incorporate the pitch rate, pitch attitude, and altitude damping augmentation. These equations were mechanized on an analog computer to obtain time histories of the aircraft response following the release of the loads. The forcing functions (Z_o and M_o) of the equations are the unbalanced normal force and pitching moment due to the release of the loads. Thus the time histories of hover mode drops begin unbalanced at zero time.

The equations of motion for the transitional and conventional flight mode analyses for the single load drops are linearized three-degree-of-freedom longitudinal equations as shown in Table XXV. These equations are simplified from the complete longitudinal equations by neglecting the products and powers of perturbations and partial derivatives with respect to rate of change except for vertical acceleration. The equations are programmed for solution by digital computer. Time histories are computed by matrix methods employing the approximation of the solution in any step by a Taylor series of an adequate number of terms to assure accuracy. Elevator deflection is employed in these equations to simulate the change in lift and pitching moment due to the release of the loads.

The equations of motion for the sequential drops using the gravity-drop technique are shown in Table XXVI. These are conventional longitudinal equations, except in this case the mass, pitching-moment of inertia, and pitching moment (ΔM) vary with time. These equations were mechanized on an analog computer employing function generators and relays to accommodate the variation of mass, pitching-moment of inertia, and pitching moment with time.

Aerodynamic, Mass, and Inertial Data

The aerodynamic coefficients and derivatives required to evaluate the coefficients of the equations of motion were determined with the use of References 21 and 109. The mass and inertial data were determined from Reference 19.

The aerodynamic, mass, and inertial data for the investigations of the cargo drops from the vertical/modular system with the aircraft in the

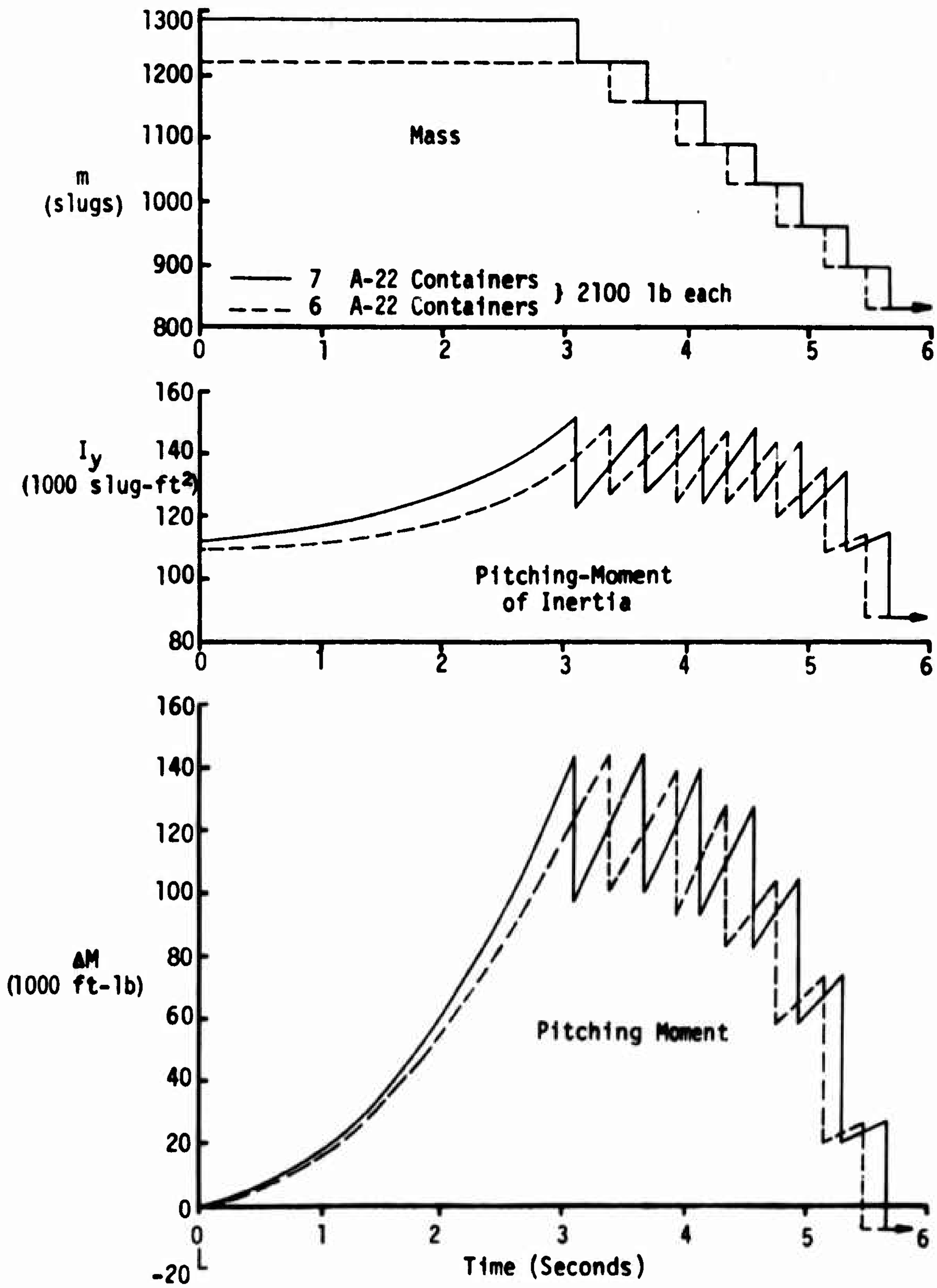


Figure 52. (U) Variation of Mass, Pitching-Moment of Inertia, and Pitching Moment with Time for the Gravity Drop of A-22 Containers ($i_w = 0^o$, $\delta_F = 30^o$).

TABLE XXIV (U)
LONGITUDINAL EQUATIONS OF MOTION
FOR THE HOVER FLIGHT MODE

$$\dot{u} = \frac{X_u}{m} u - g \theta + \frac{X_o}{m}$$

$$\dot{w} = \frac{Z_w}{m} w + \frac{Z_o}{m}$$

$$\ddot{\theta} = \frac{M_q}{I_y} \dot{\theta} + \frac{M_\theta}{I_y} \theta + \frac{M_u}{I_y} u + \frac{M_w}{I_y} w + \frac{M_{\delta_{s_e}}}{I_y} \delta_{s_e} + \frac{M_o}{I_y}$$

TABLE XXV (U)
LONGITUDINAL EQUATIONS OF MOTION FOR THE CONVENTIONAL AND TRANSITIONAL FLIGHT MODES

X - Equation

$$U\left(\frac{m}{qS}s - \frac{T_u}{qS}\cos\xi_T + C_{D_u} + \frac{2}{U_1}C_{D_1}\right) + \alpha\left(\frac{m}{qS}\dot{\theta}_1 U_1 - C_{L_1} + C_{D_\alpha}\right) + \theta\left(\frac{mg}{qS}\cos\gamma_1\right) + \delta_e\left(C_{D_{\delta_e}}\right) + \left(\frac{T_u}{qS}\cos\xi_T - C_{D_u}\right)U_1 + \left(C_{L_1} - C_{D_\alpha}\right)\alpha_1 - \frac{m}{qS}U_1\alpha_1\dot{\theta}_1 + \frac{mg}{qS}\sin\gamma_1 - \frac{mg}{qS}\cos\gamma_1\theta_1 - C_{D_1} - \frac{T_1\cos\xi_T}{qS} = 0$$

Z - Equation

$$U\left(-\frac{m}{qS}\dot{\theta}_1 + \frac{T_u}{qS}\sin\xi_T + \frac{2}{U_1}C_{L_1} + C_{L_u}\right) + \alpha\left(\frac{mU_1}{qS}s + \frac{t_w}{2U}C_{L_{D_\alpha}}s + C_{L_\alpha} + C_{D_1}\right) + \theta\left(\frac{t_w}{2U_1}C_{L_q}s - \frac{mU_1}{qS} + \frac{mg}{qS}\sin\gamma_1\right) + \delta_e\left(C_{L_{\delta_e}}\right) + \left(-\frac{T_u}{qS}\sin\xi_T - C_{L_u}\right)U_1 - \left(C_{L_\alpha} + C_{D_1}\right)\alpha_1 + \left(\frac{mU_1}{qS} - \frac{t_w}{2U_1}C_{L_q}\right)\dot{\theta}_1 - \frac{mg}{qS}\cos\gamma_1 - \frac{mg}{qS}\sin\gamma_1\theta_1 - C_{L_1} + \frac{T_1\sin\xi_T}{qS} = 0$$

M - Equation

$$U\left(-\frac{T_u}{qS}\frac{Z_T}{t_w} - \frac{2}{U_1}C_{m_1} - C_{m_u}\right) + \alpha\left(-\frac{t_w}{2U_1}C_{m_{D_\alpha}}s - C_{m_\alpha}\right) + \theta\left(\frac{I_y}{qSt_w}s^2 - \frac{t_w}{2U_1}C_{m_q}s\right) + \delta_e\left(-C_{m_{\delta_e}}\right) + \left(\frac{T_u Z_T}{qSt_w} + C_{m_u}\right)U_1 + C_{m_\alpha}\alpha_1 + C_{m_q}\frac{t_w}{2U_1}\dot{\theta}_1 + C_{m_1} - \frac{T_1 Z_T}{qSt_w} = 0$$

TABLE XXVI (U)
LONGITUDINAL EQUATIONS OF MOTION FOR THE SEQUENTIAL AIRDROP OF A-22 CONTAINERS FROM THE CONVENTIONAL FLIGHT MODE

$$\dot{u} = \frac{X_w}{m} w - g\theta$$

$$\dot{w} = \frac{Z_w}{m} w + \frac{Z_q}{m} \dot{\theta} - u_o \dot{\theta}$$

$$\ddot{\theta} = \frac{1}{I_y} \left[M_u u + M_w w + M_{\dot{w}} \dot{w} + M_q \dot{\theta} + M_\theta \theta + \Delta M \right]$$

where m, I_y, and ΔM are functions of time.

hover, transitional, and conventional flight modes are shown in Tables XXI, XXII, and XXIII, respectively. Similar data for the sequential drop of six and seven A-22 containers from the conventional aerial delivery system are shown in Table XXVII and Figure 52.

RESULTS

Vertical/Modular Delivery System

The aircraft response to the vertical release of the nine loads investigated with the aircraft in the hover mode is shown in Figures 53 through 61. Full pitch rate and altitude damping, and pitch attitude hold augmentation are utilized for these drops. No pilot or control system dynamics are included. The time histories indicate that the aircraft excursions are small and could be controlled by the pilot.

Time histories of the aircraft response to the vertical release of the nine loads from the aircraft in the transitional flight mode ($i_W = 10^o$, $\delta_F = 60^o$) are shown in Figures 62 through 70. No stability augmentation, pilot inputs or control system dynamics were included in these studies. The safe operating limits established for this configuration are the structural-limit, normal load-factor of 4.2g's and an angle of attack of 2.5 degrees, corresponding to 0.8 of the maximum lift available. The results indicate that the structural limits of the aircraft are not exceeded and that the moderate to large pitch and angle of attack excursions could be controlled by the pilot. The use of pitch rate damping augmentation in this flight mode would reduce these excursions to readily acceptable values.

The results of the studies of the response of the aircraft in the conventional flight mode ($i_W = 0^o$, $\delta_F = 30^o$) to the vertical release of the nine single loads as shown in Figures 71 through 79 indicated no stability, control or structural limit problems. No pilot inputs or stabilility augmentation is included in the time histories. A structural-limit, normal load-factor of 4.2g's and an angle of attack of 12 degrees, corresponding to 0.8 of the maximum lift available, were established as safe operating limits for this configuration. Moderate aircraft excursions in this configuration are permissible since drops are normally made at altitudes above 500 feet.

Conventional Aerial Delivery System

The aircraft response to the sequential drop of six and seven A-22 containers was determined with aircraft in the conventional flight mode ($i_W = 0^o$, $\delta_F = 30^o$) and equipped with a gravity extraction system. No pilot inputs or stability augmentation system dynamics were included in these investigations. Stability augmentation in the form of pitch rate damping and attitude hold, where employed, was that available from the unit horizontal tail with full gain; the tail propeller was disengaged.

The aircraft response to the sequential drop of six A-22 containers is shown in Figures 80, 81, and 82 for no stability augmentation, pitch rate damping augmentation, and pitch rate damping augmentation plus attitude

hold, respectively. Similar data are shown for the sequential drop of seven A-22 containers in Figures 83, 84, and 85. The safe operating limits of an angle-of-attack change of 7 degrees, corresponding to 0.8 of the maximum lift available, and the structural-limit, normal load factors as shown in Figures 80 and 83 were established for this configuration. These data indicate that six or seven containers may be dropped safely only if pitch rate damping augmentation and attitude hold are employed to prevent excessive excursions in angle of attack and normal load factor.

CONCLUSIONS

Within the limitations of the analysis, the release of cargo from the aircraft equipped with the vertical/modular delivery system is possible from a stability and control standpoint. The use of stability augmentation is desirable for low-altitude drops using the transitional flight mode.

The sequential drop of six or seven A-22 containers of 2100 pounds each requires pitch rate damping augmentation and attitude hold to prevent dangerous excursions of angle of attack and normal load factor.

RECOMMENDATIONS

Should the vertical/modular delivery system prove effective, a more thorough stability and control analysis of any vehicle equipped with such system is recommended.

The problem of steady-state excursions of the aircraft center of gravity when partial loads are dropped from the vertical/modular system requires further study. Possible solutions to the problem are greater allowable center-of-gravity limits at the expense of airframe weight and drag or an onboard computer which indicates which loads can be released without resulting in an out-of-limits center of gravity as described in the Vertical/Modular Delivery Design chapter.

TABLE XXVII (U)

AERODYNAMIC DATA FOR THE STABILITY AND CONTROL ANALYSIS OF THE SEQUENTIAL DROP OF SIX AND SEVEN A-22 CONTAINERS. $i_w = 0^o$, $\delta_F = 30^o$

		Six Containers	Seven Containers
Initial Gr. Wt. (lb)		39,410	41,510
u_o	(ft/sec)	206.0	211.0
$\alpha_o = \theta_o$	(deg)	5.0	5.0
X_u	(lb-sec/ft)	-87.0	-89.0
Z_w	(lb-sec/ft)	-824.0	-844.0
Z_q	(lb-sec/rad)	-3830.0	-3924.0
M_w	(lb-sec)	-791.0	-810.0
$M_{\dot{w}}$	(lb-sec^2)	-149.0	-149.0
M_θ	(ft-lb/rad)	0(-183,500)*	0(-192,000)*
M_q	(ft-lb-sec/rad)	-93,335.0(-465,335)	-95,617.0(-485,617)

*Values in parentheses indicate total including augmentation.

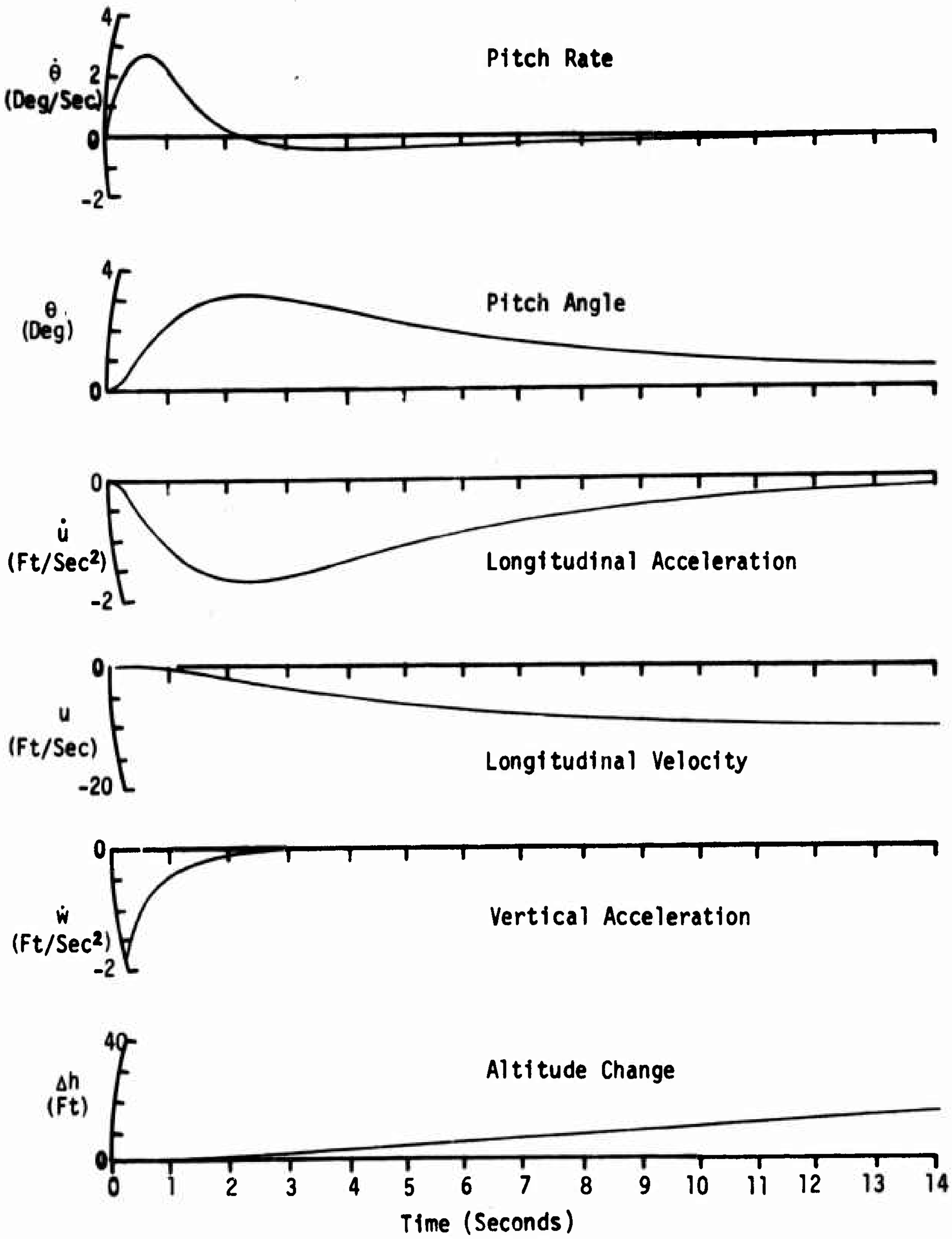


Figure 53. (U) Time History of Aircraft Motion Following the Airdrop of 1475 Pounds from Fuselage Station 90 – Hover Mode.

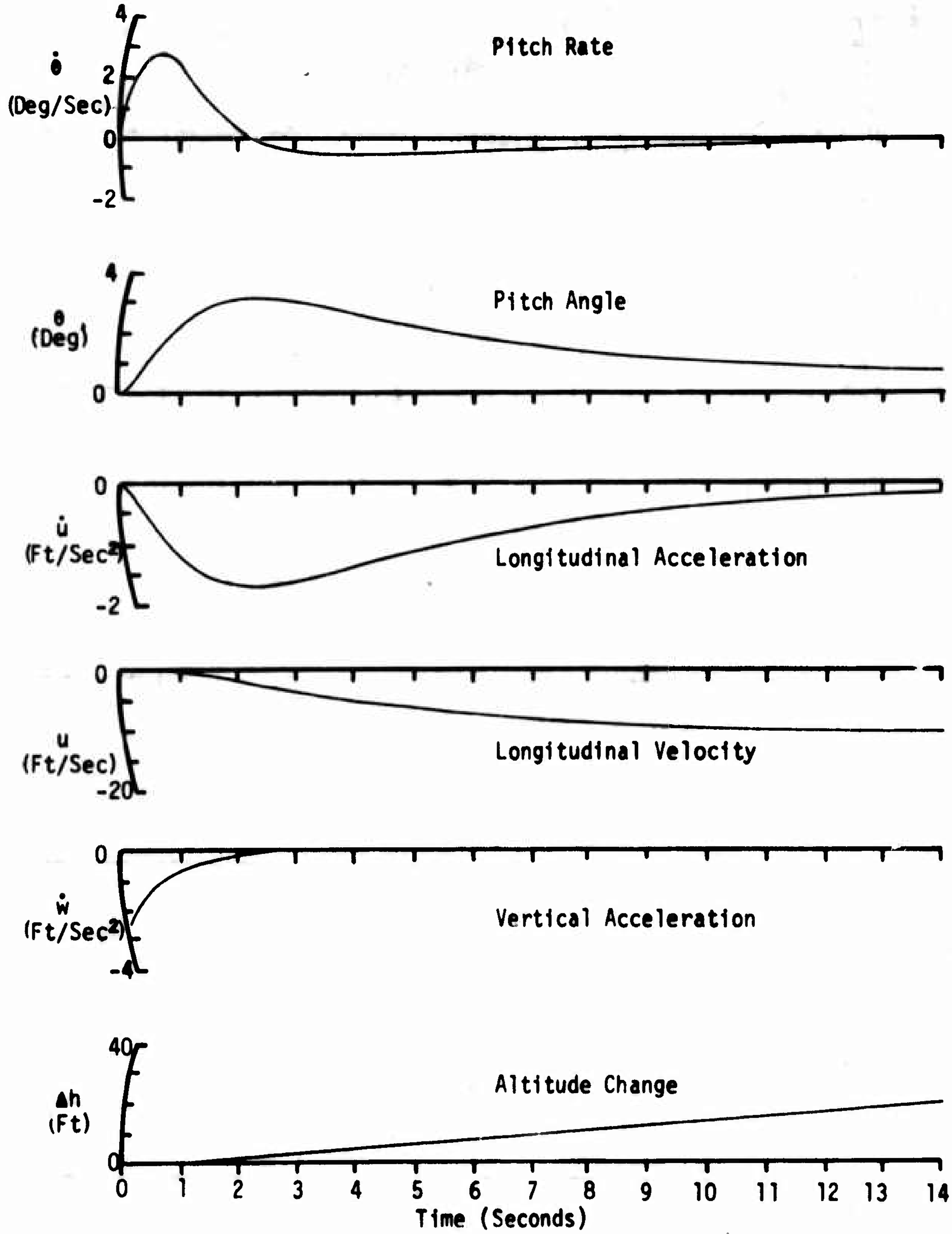


Figure 54. (U) Time History of Aircraft Motion Following the Airdrop of 2000 Pounds from Fuselage Station 135 – Hover Mode.

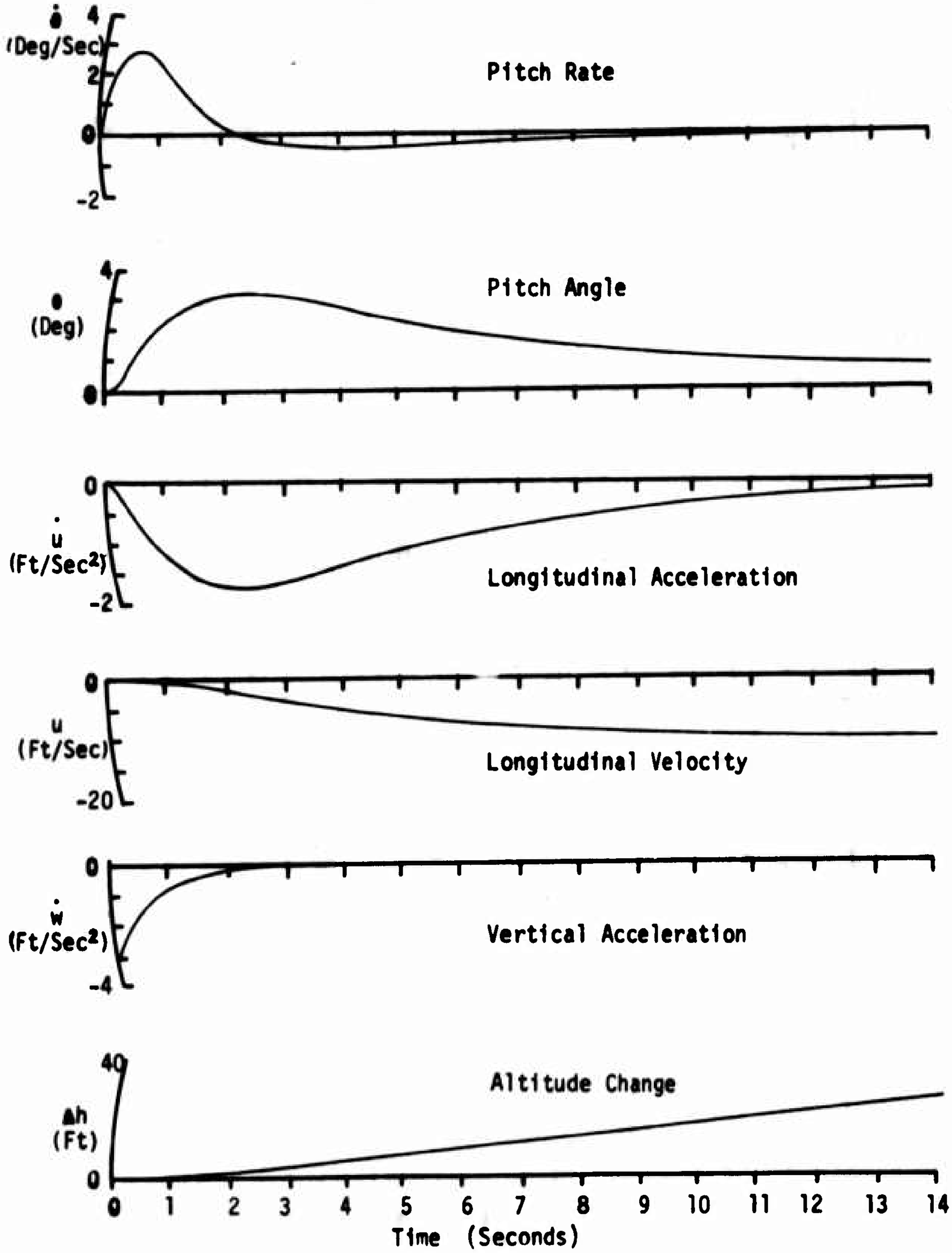


Figure 55. (U) Time History of Aircraft Motion Following the Airdrop of 2500 Pounds from Fuselage Station 160 – Hover Mode.

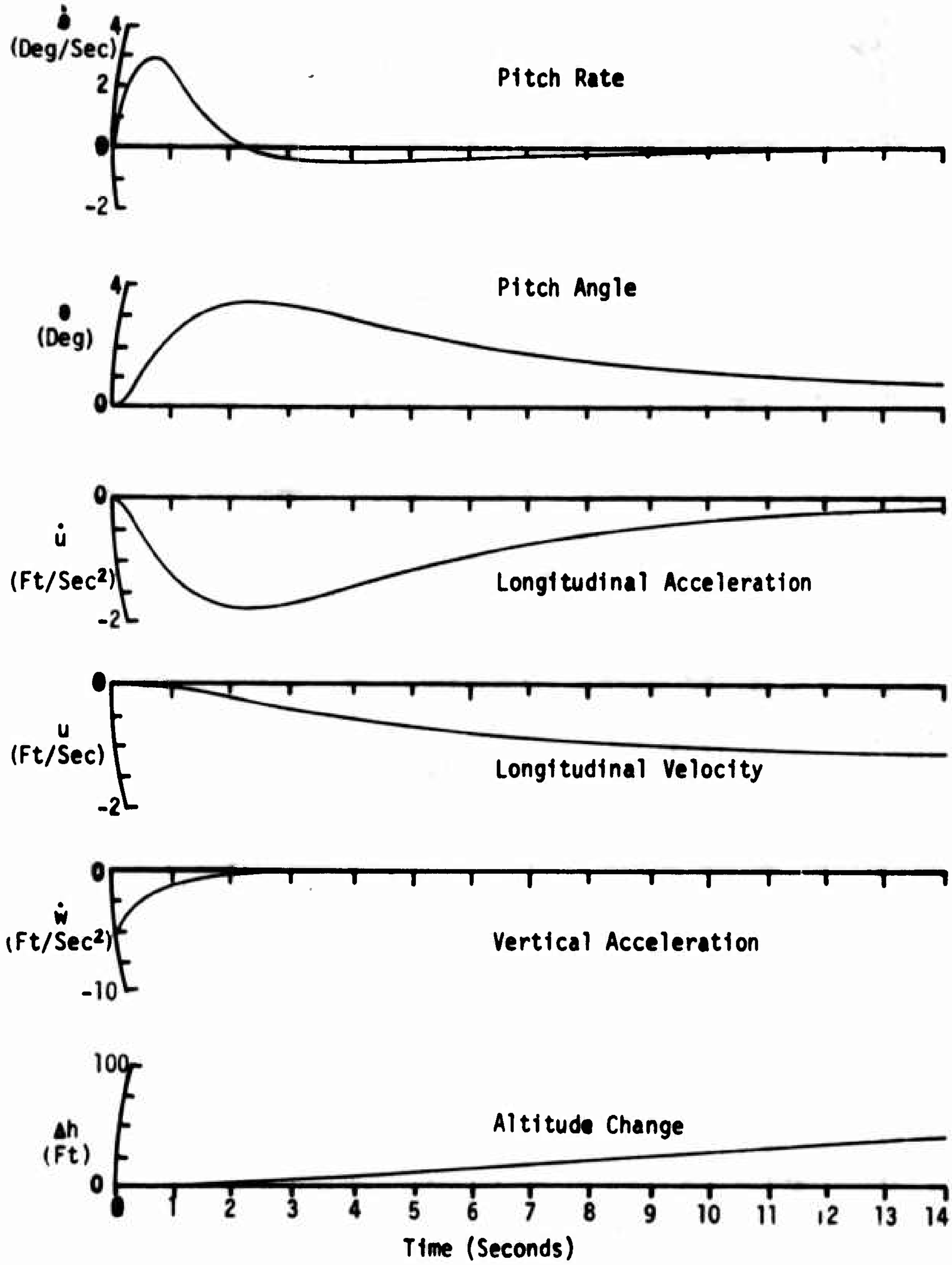


Figure 56. (U) Time History of Aircraft Motion Following the Airdrop of 4000 Pounds from Fuselage Station 220 – Hover Mode.

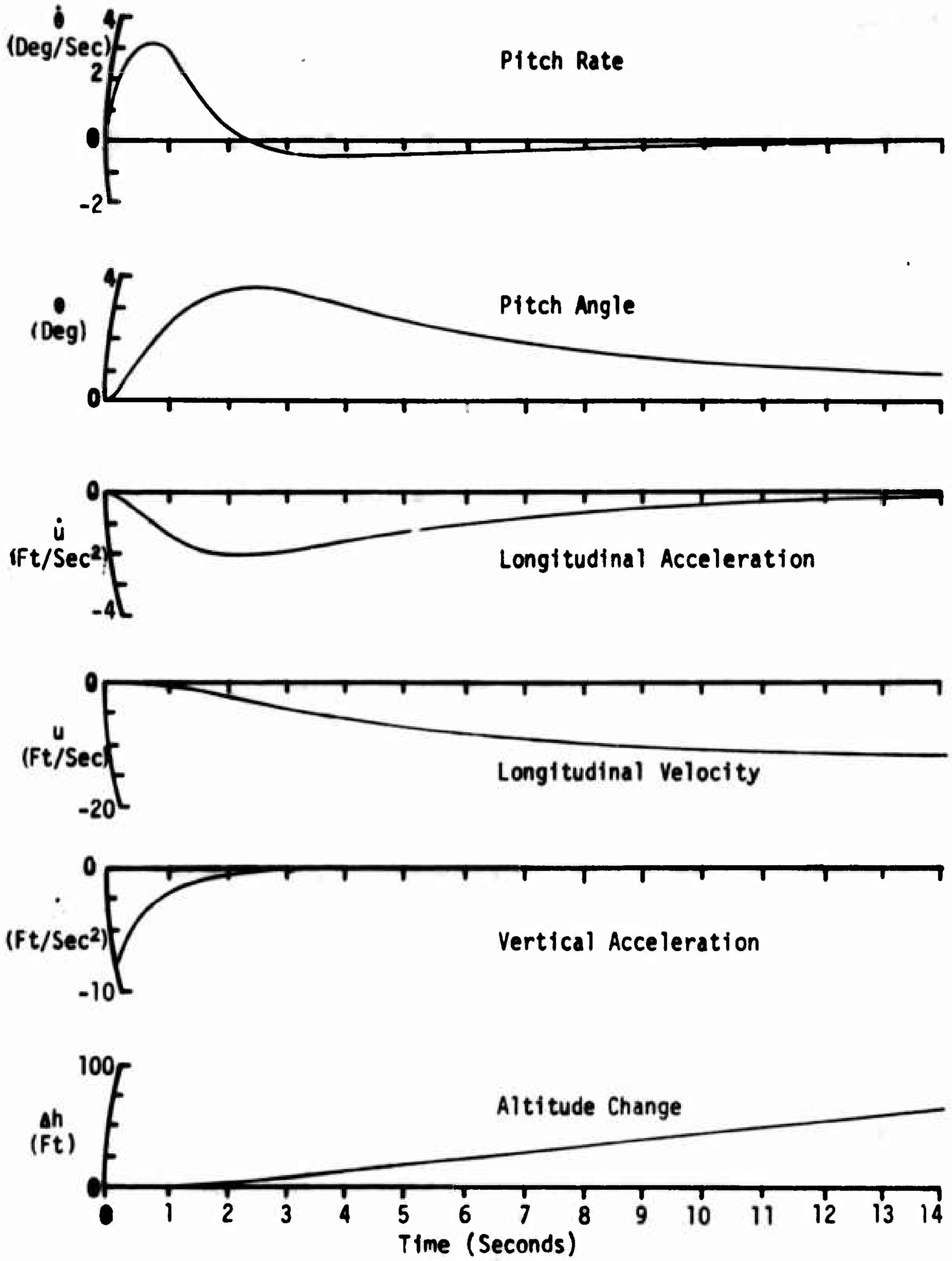


Figure 57. (U) Time History of Aircraft Motion Following the Airdrop of 6250 Pounds from Fuselage Station 220 – Hover Mode.

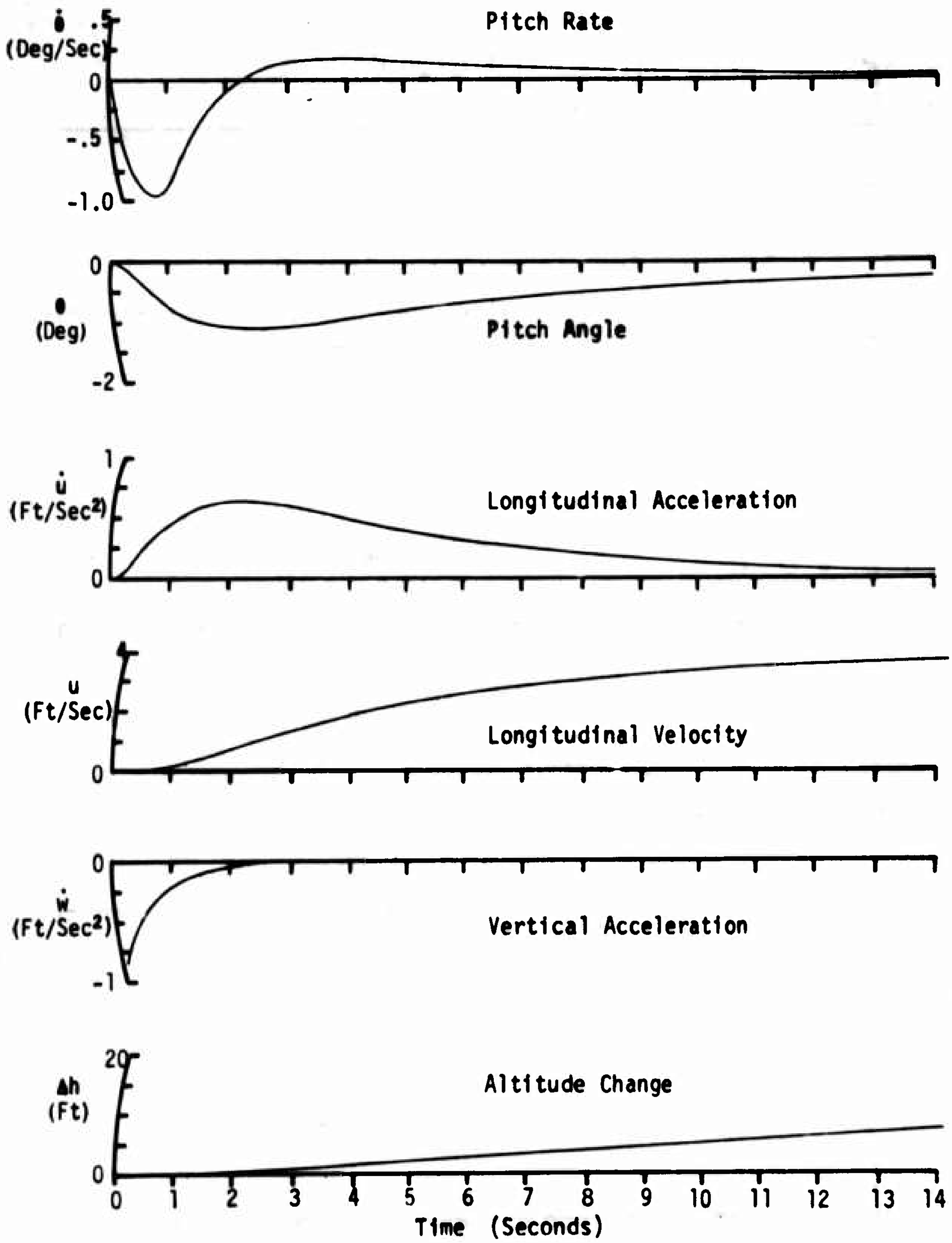


Figure 58. (U) Time History of Aircraft Motion Following the Airdrop of 700 Pounds from Fuselage St..tion 400 – Hover Mode.

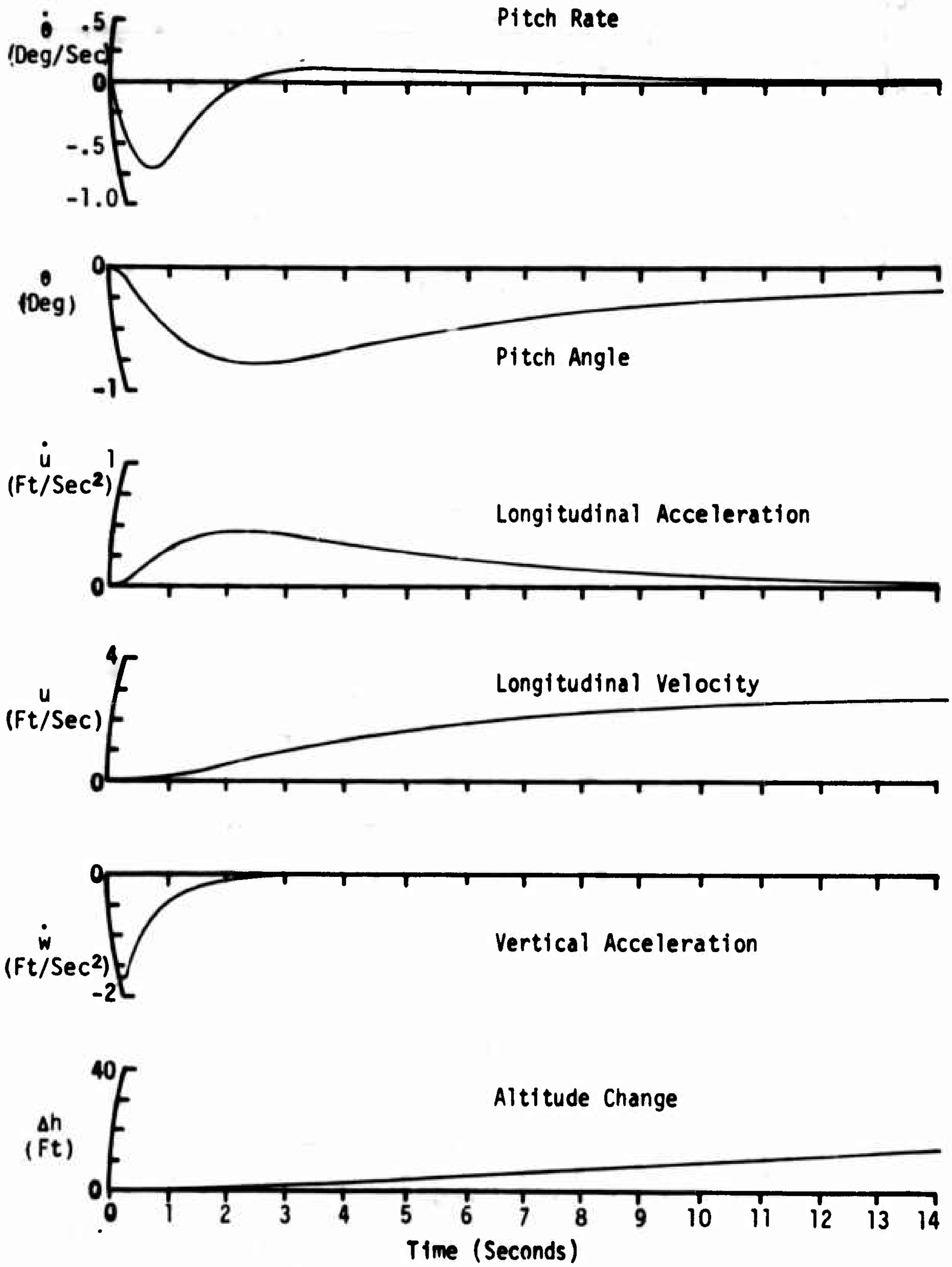


Figure 59. (U) Time History of Aircraft Motion Following the Airdrop of 1400 Pounds from Fuselage Station 340 — Hover Mode.

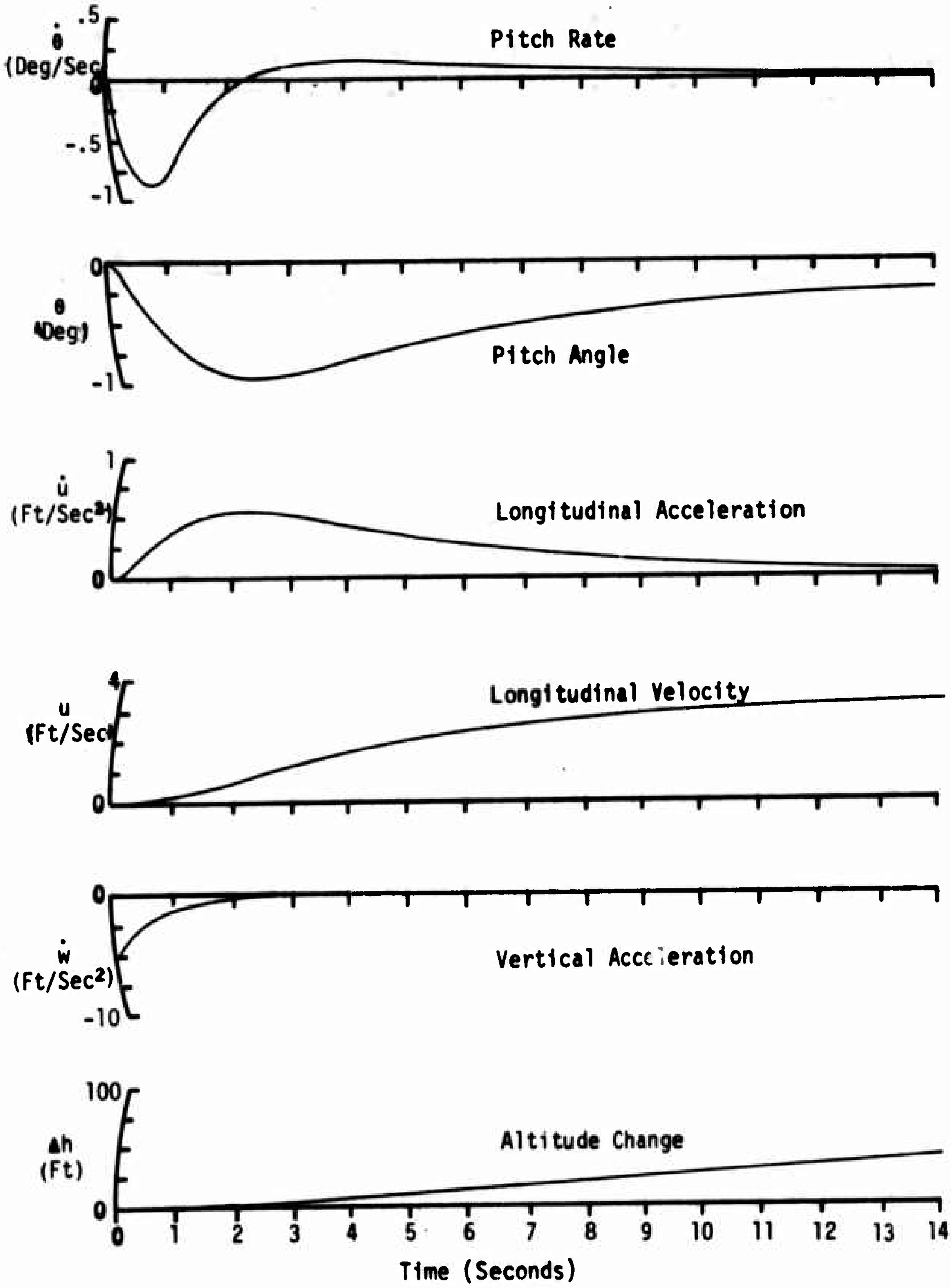


Figure 60. (U) Time History of Aircraft Motion Following the Airdrop of 4000 Pounds at Fuselage Station 280 – Hover Mode.

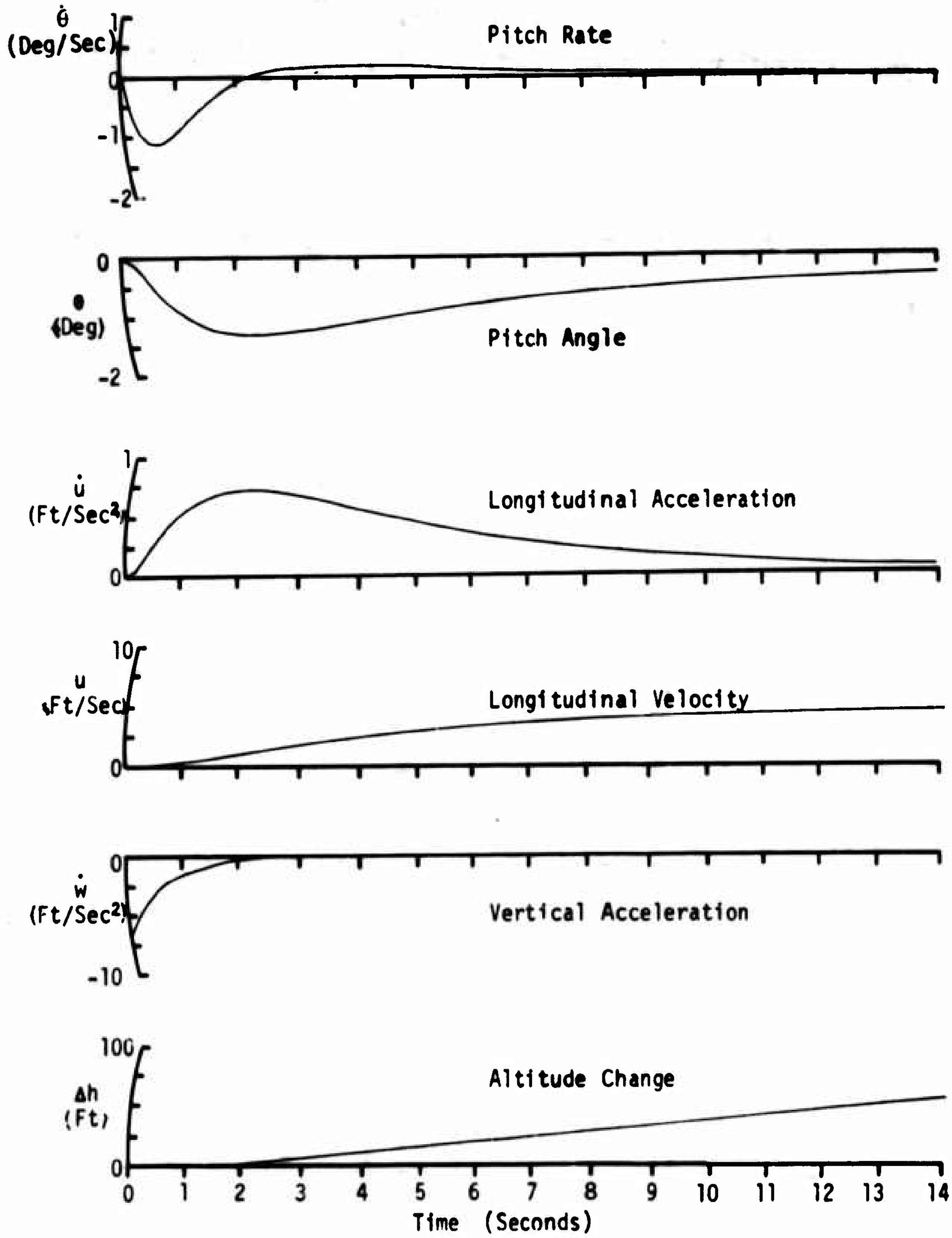


Figure 61. (U) Time History of Aircraft Motion Following the Airdrop of 5400 Pounds from Fuselage Station 280 – Hover Mode.

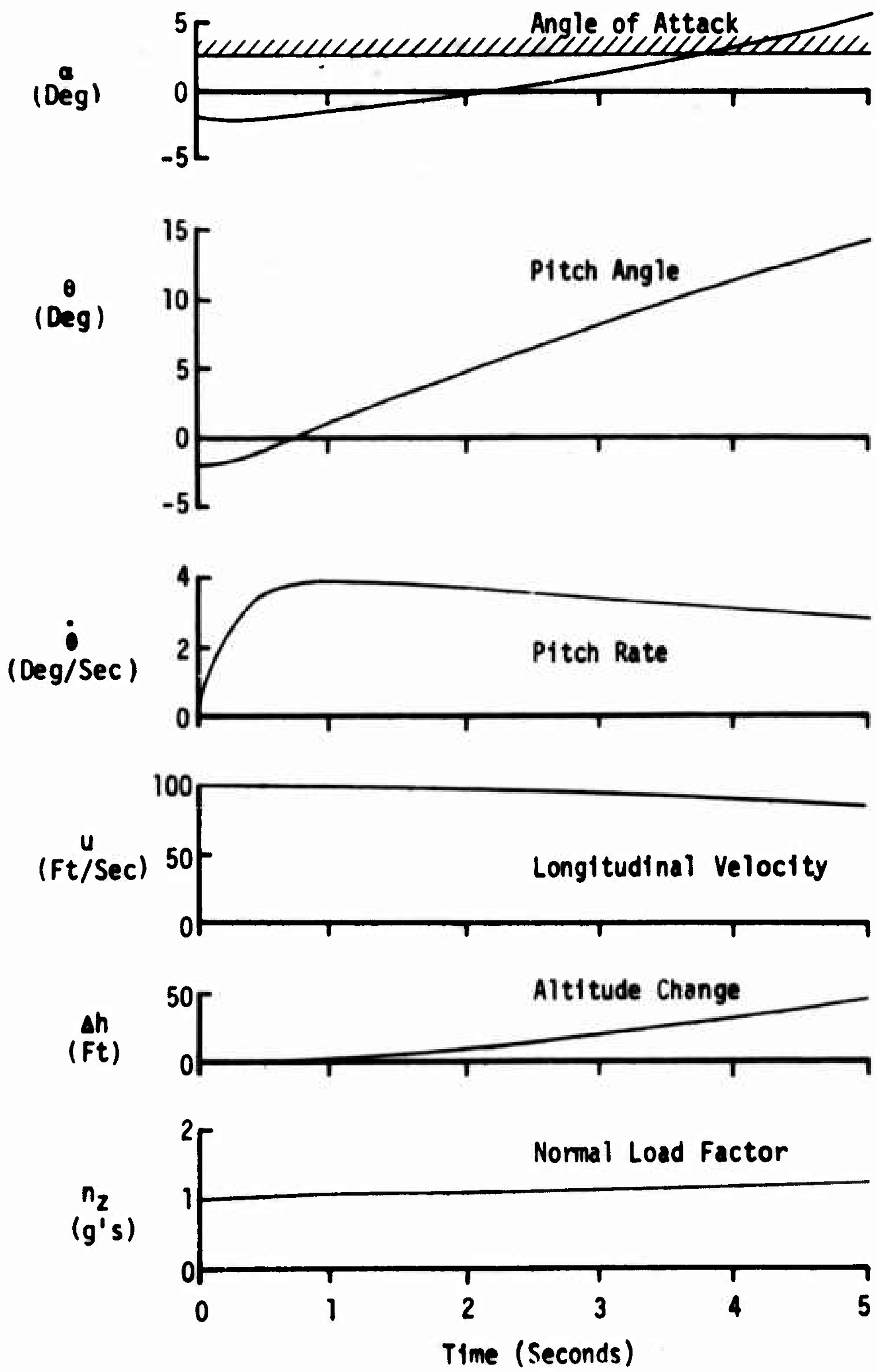


Figure 62. (U) Time History of Aircraft Motion Following the Airdrop of 1475 Pounds from Fuselage Station 90 – $i_w = 10^o$, $\delta_F = 60^o$.

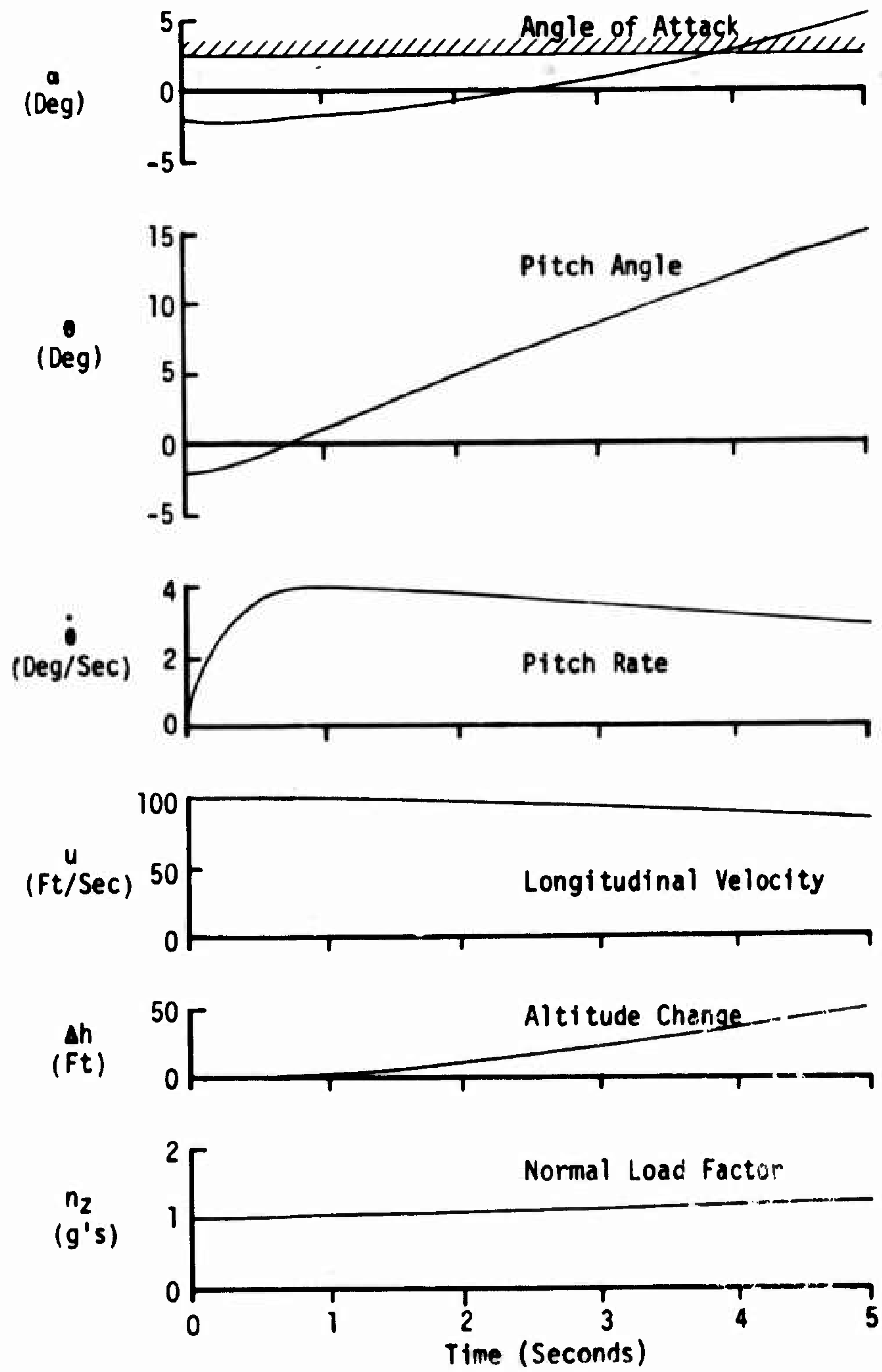


Figure 63. (U) Time History of Aircraft Motion Following the Airdrop of 2000 Pounds from Fuselage Station 135 – $i_w = 10^\circ$, $\delta_F = 60^\circ$.

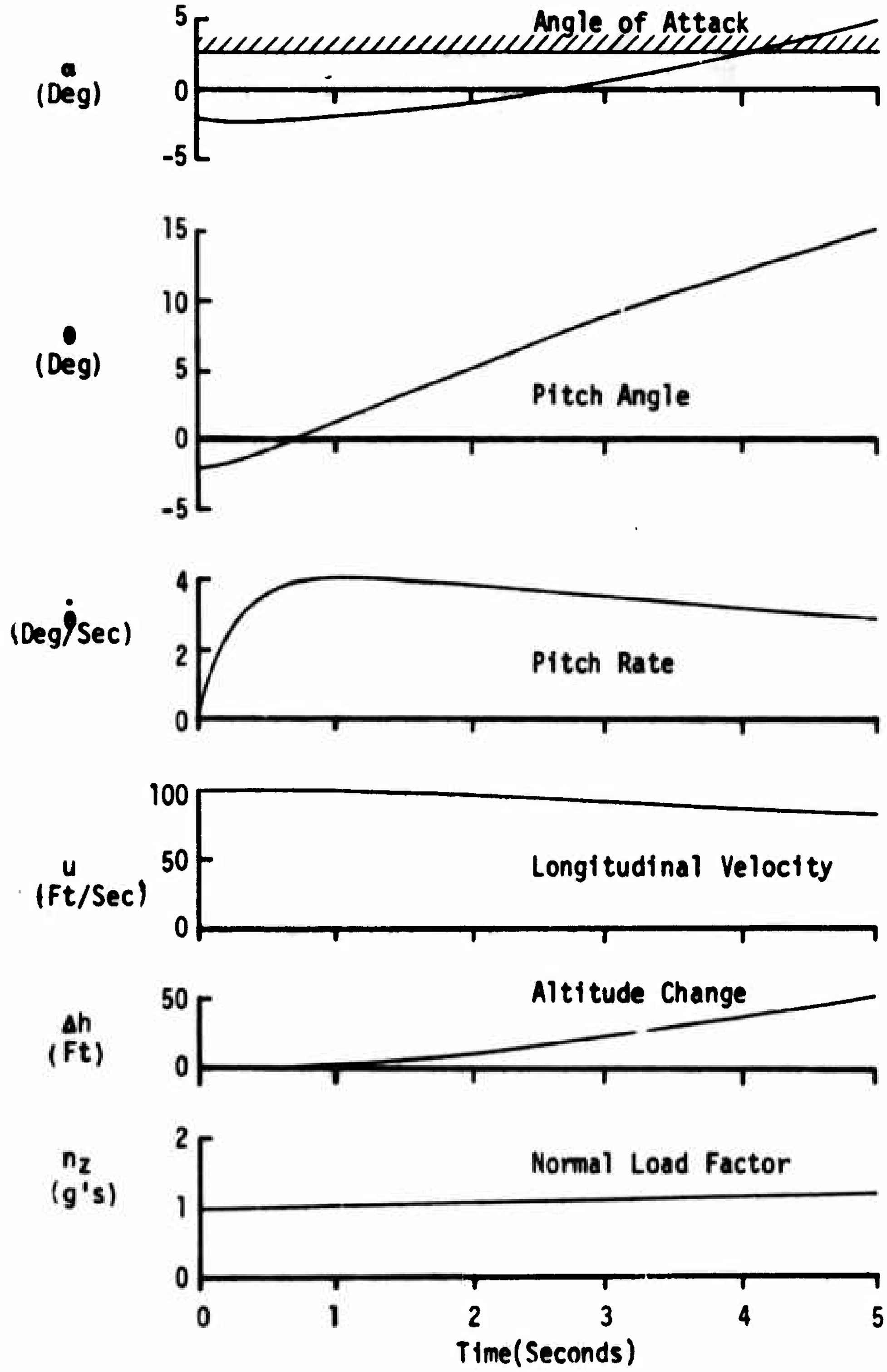


Figure 64. (U) Time History of Aircraft Motion Following the Airdrop of 2500 Pounds from Fuselage Station 160 – $i_w = 10°$, $\delta_F = 60°$.

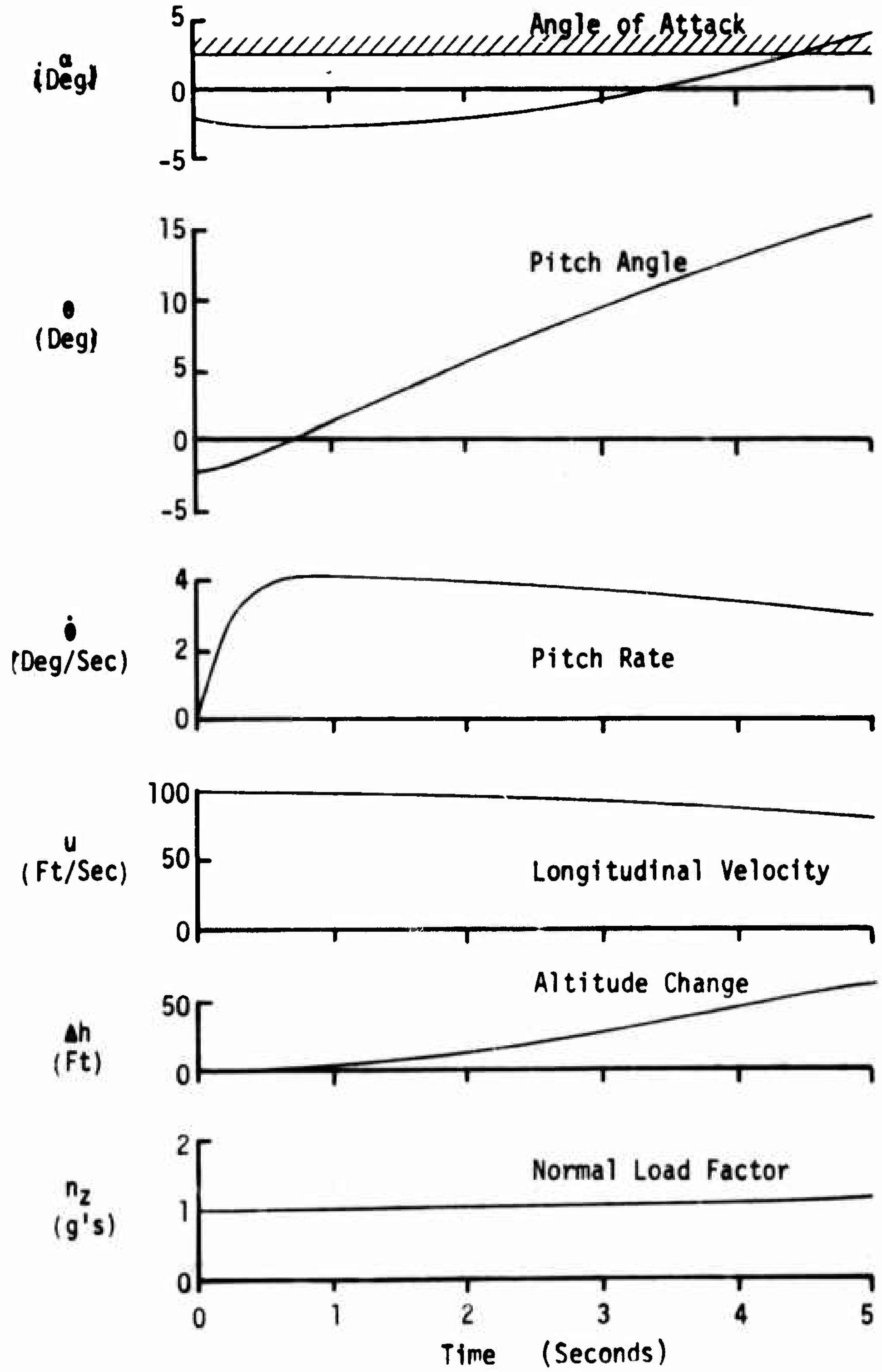


Figure 65. (U) Time History of Aircraft Motion Following the Airdrop of 4000 Pounds from Fuselage Station 220 – $i_w = 10^\circ$, $\delta_F = 60^\circ$.

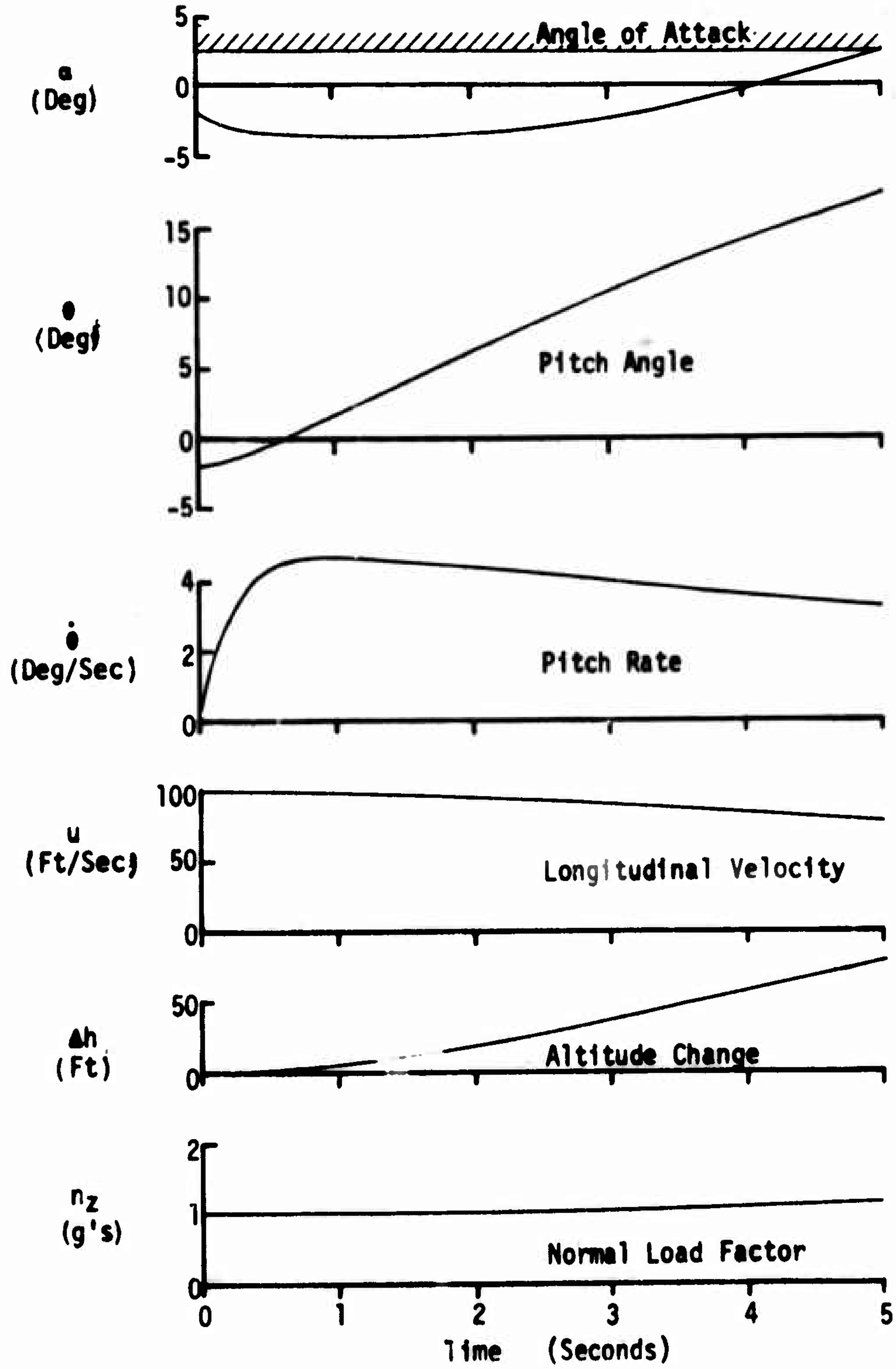


Figure 66. (U) Time History of Aircraft Motion Following the Airdrop of 6250 Pounds from Fuselage Station 220 – $i_w = 10^o$, $\delta_F = 60^o$.

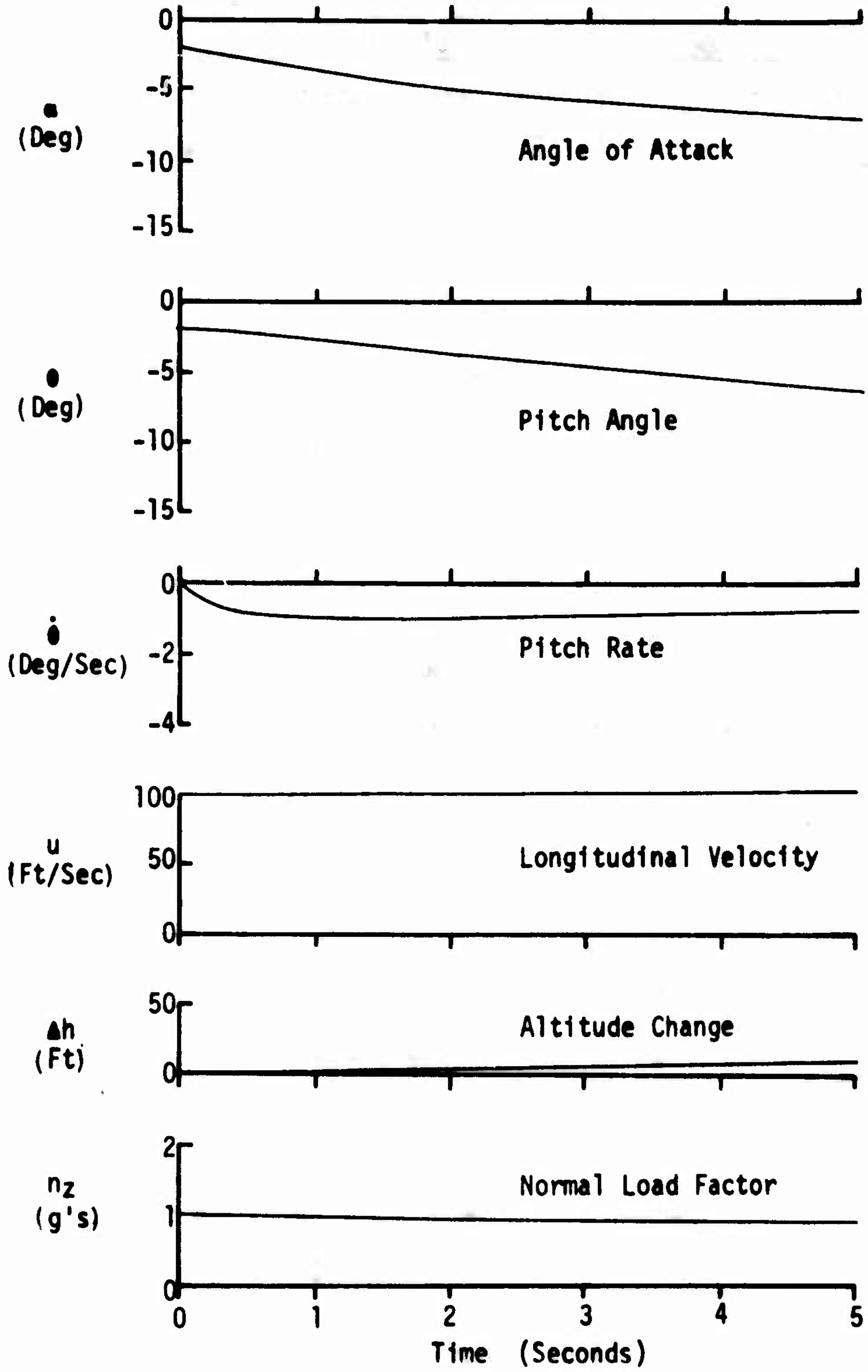


Figure 67. (U) Time History of Aircraft Motion Following the Airdrop of 700 Pounds from Fuselage Station 400 – $i_w = 10^{\circ}$, $\delta_F = 60^{\circ}$.

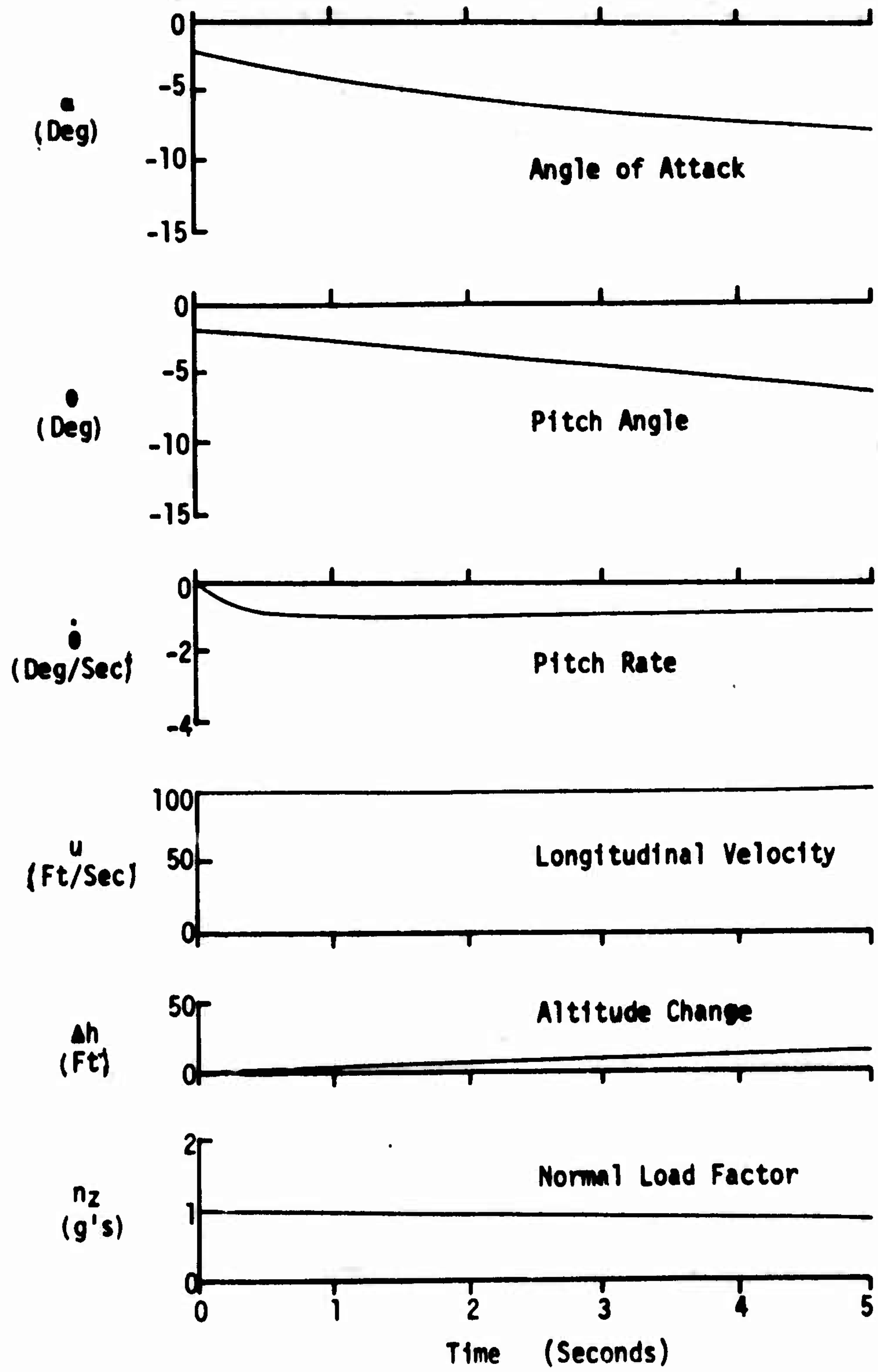


Figure 68. (U) Time History of Aircraft Motion Following the Airdrop of 1400 Pounds from Fuselage Station 340 – $i_w = 10°$, $\delta_F = 60°$.

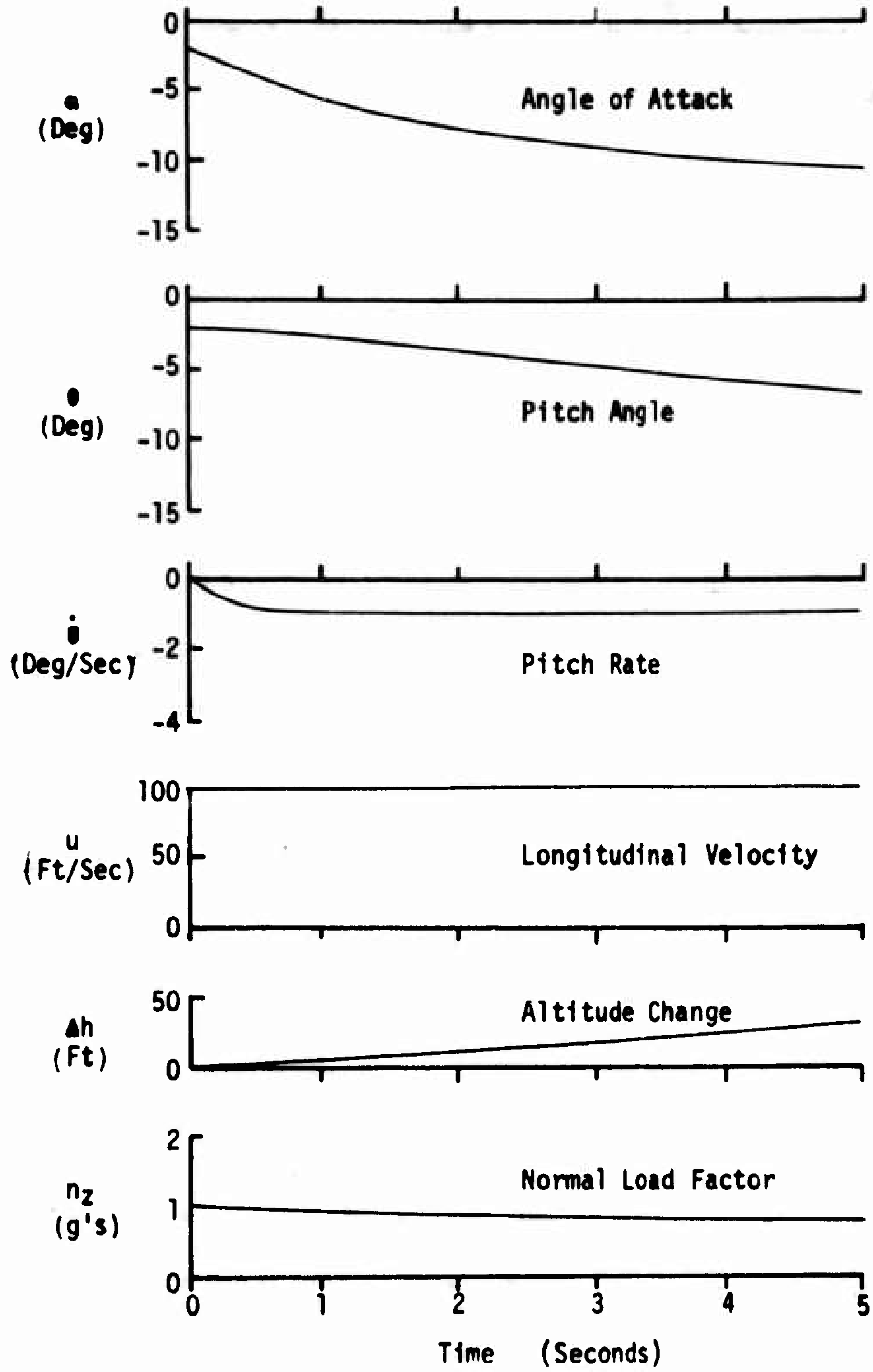


Figure 69. (U) Time History of Aircraft Motion Following the Airdrop of 4000 Pounds from Fuselage Station 280 – $i_w = 10^\circ$, $\delta_F = 60^\circ$.

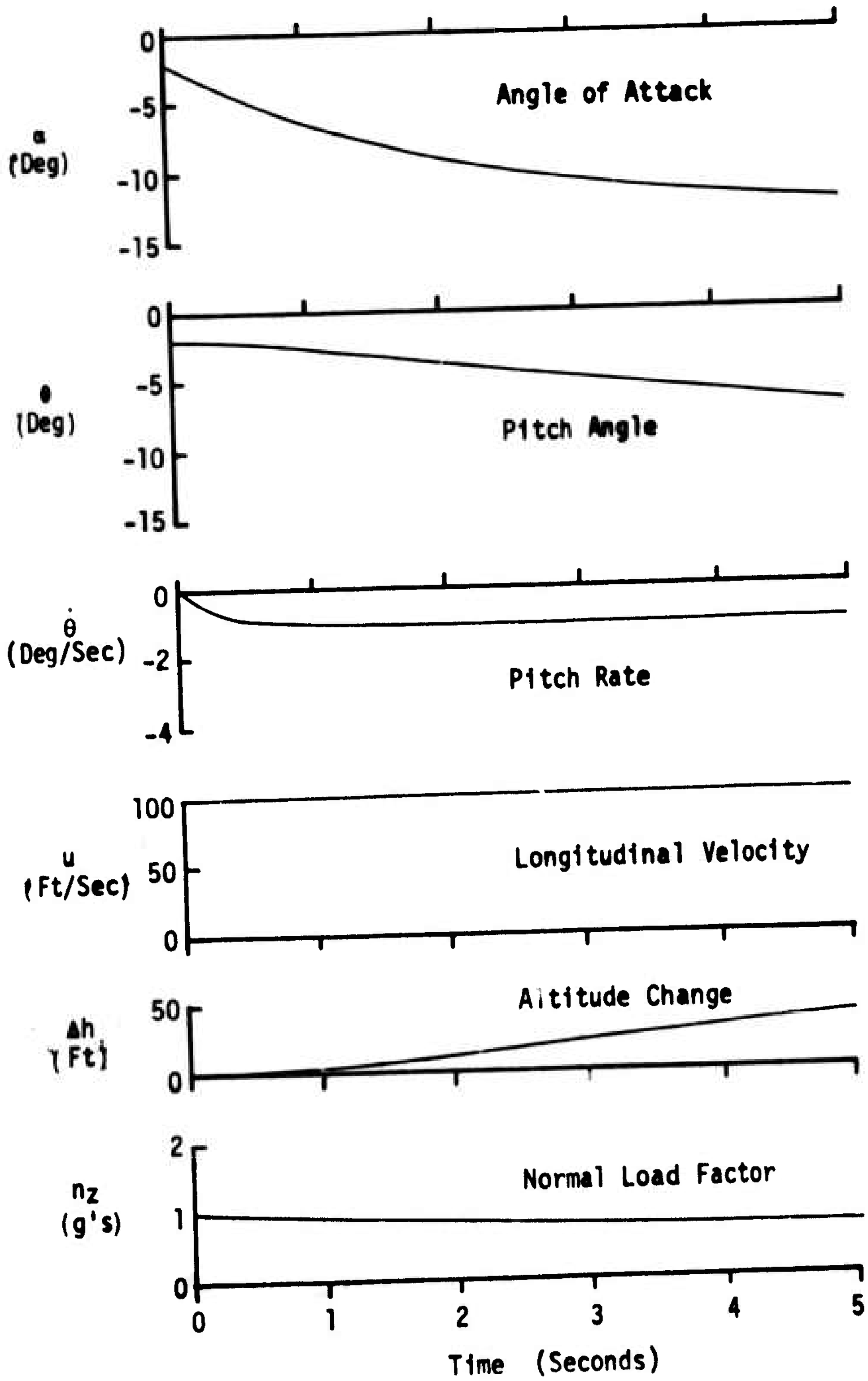


Figure 70. (U) Time History of Aircraft Motion Following the Airdrop of 5400 Pounds at Fuselage Station 280 – i_w = 10°, δ_F = 60°.

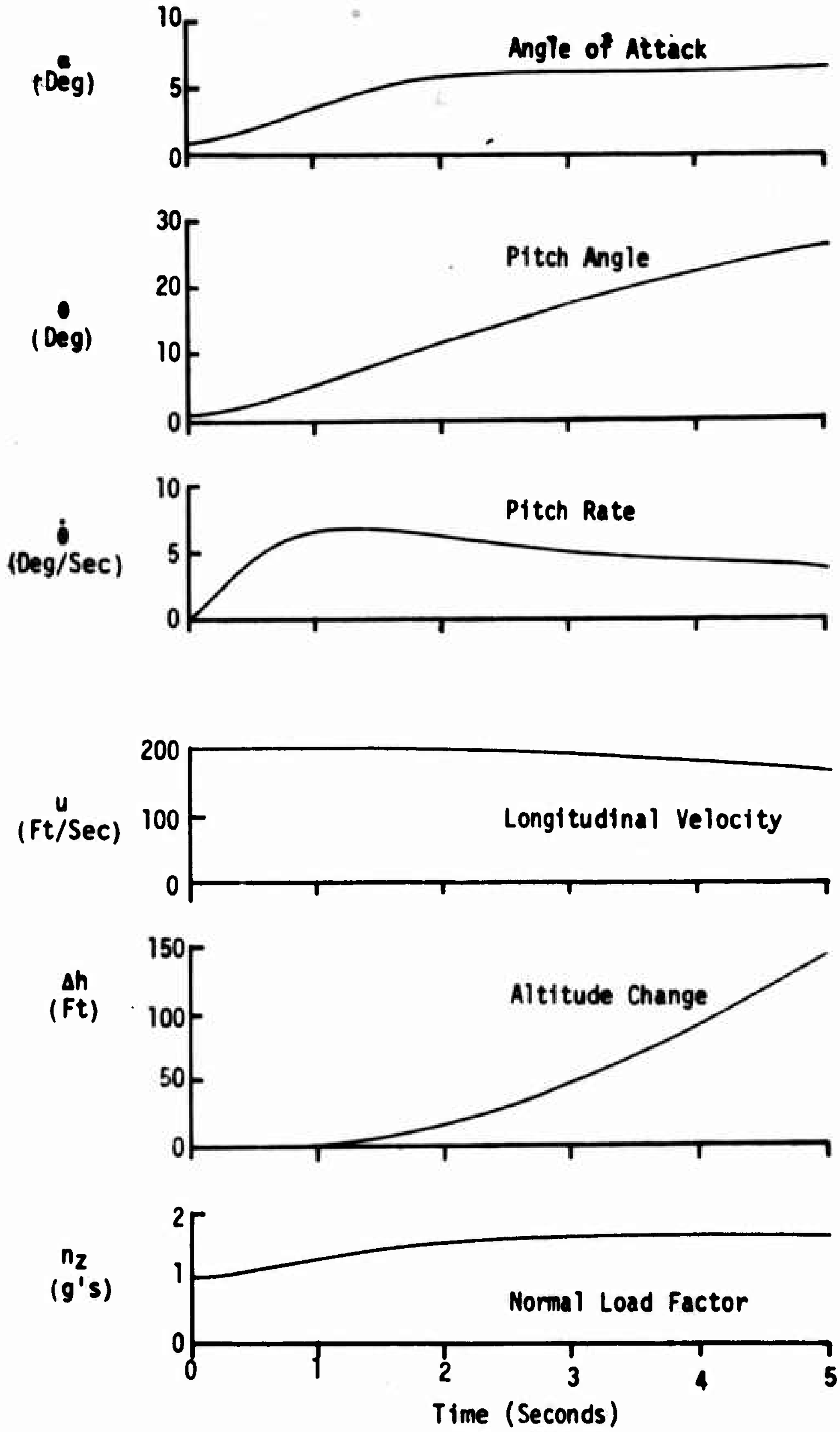


Figure 71. (U) Time History of Aircraft Motion Following the Airdrop of 1475 Pounds from Fuselage Station 90 – $i_w = 0^o$, $\delta_F = 30^o$.

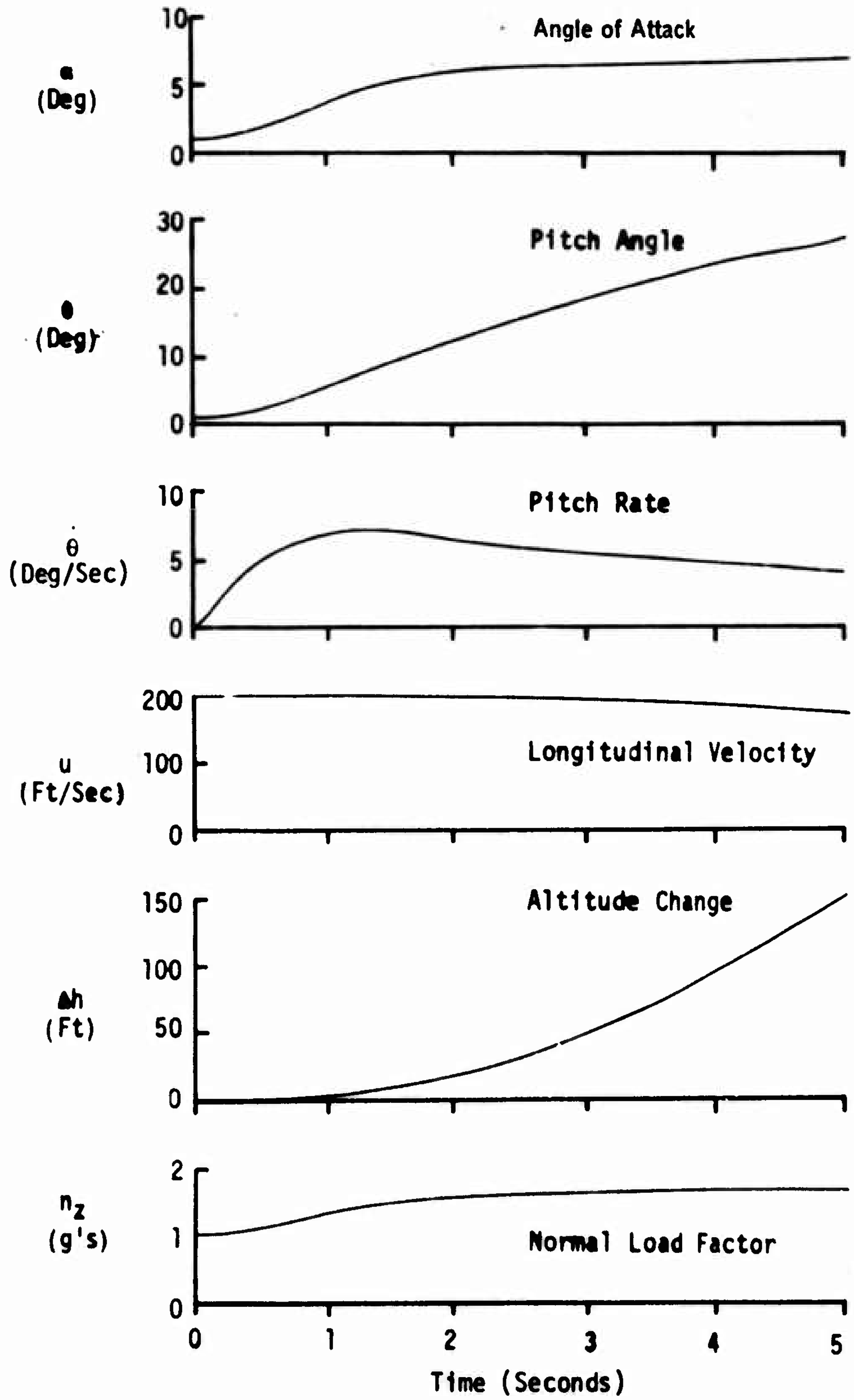


Figure 72. (U) Time History of Aircraft Motion Following the Airdrop of 2000 Pounds from Fuselage Station 135 – $i_w = 0^\circ$, $\delta_F = 30^\circ$.

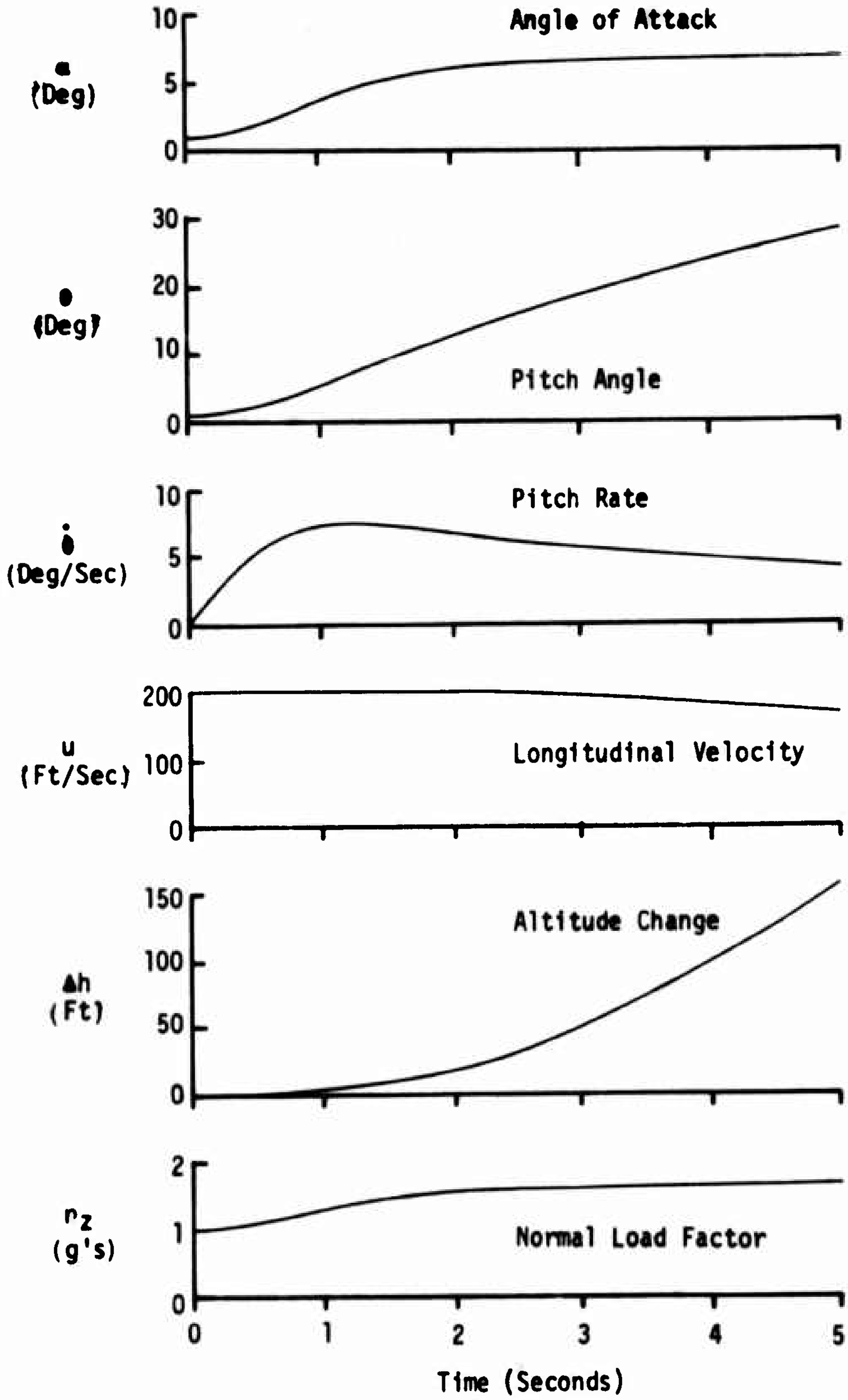


Figure 73. (U) Time History of Aircraft Motion Following the Airdrop of 2500 Pounds from Fuselage Station 160 – $i_w = 0°$, $\delta_F = 30°$.

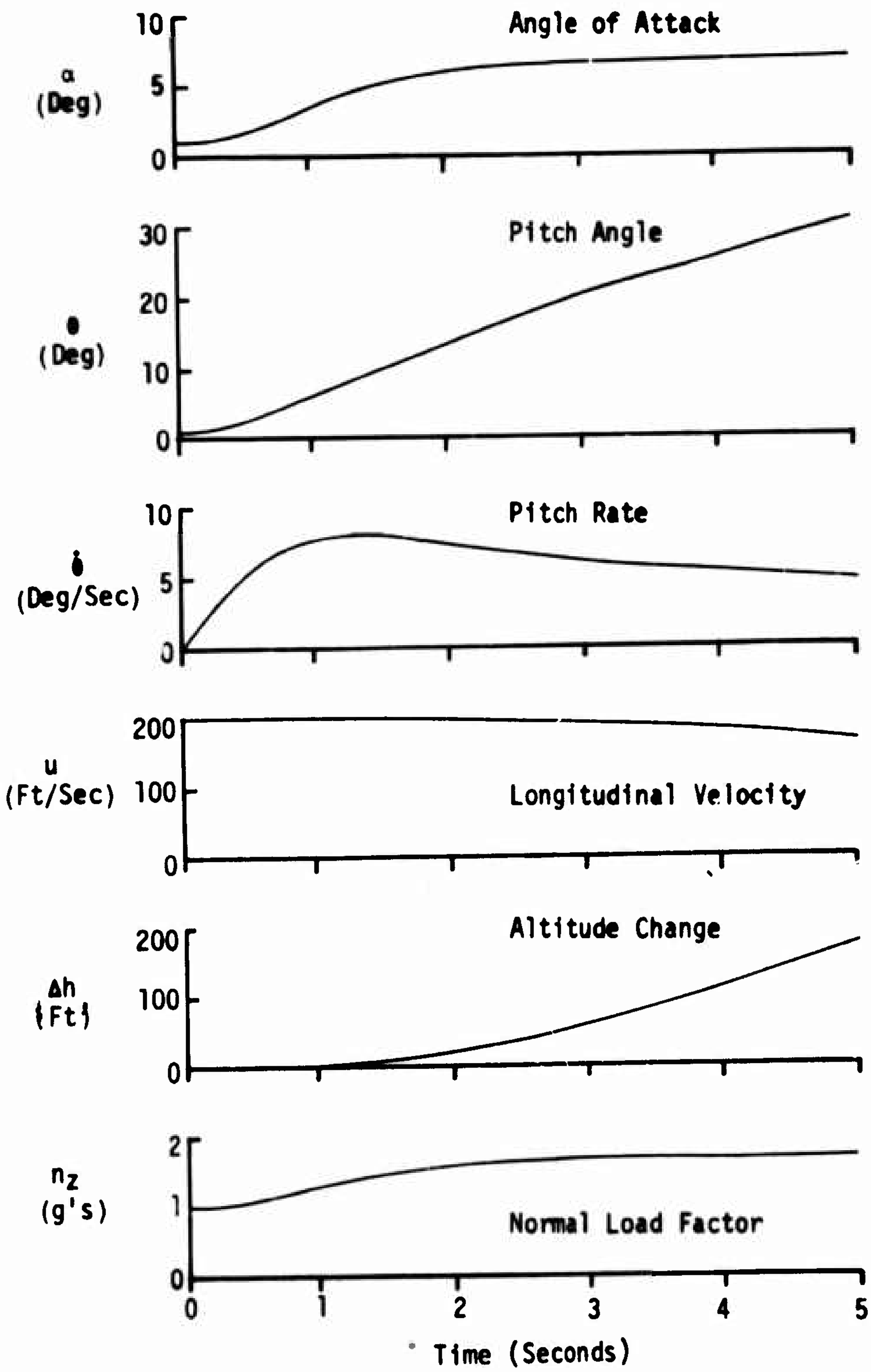


Figure 74. (U) Time History of Aircraft Motion Following the Airdrop of 4000 Pounds from Fuselage Station 220 – $i_w = 0^o$, $\delta_F = 30^o$.

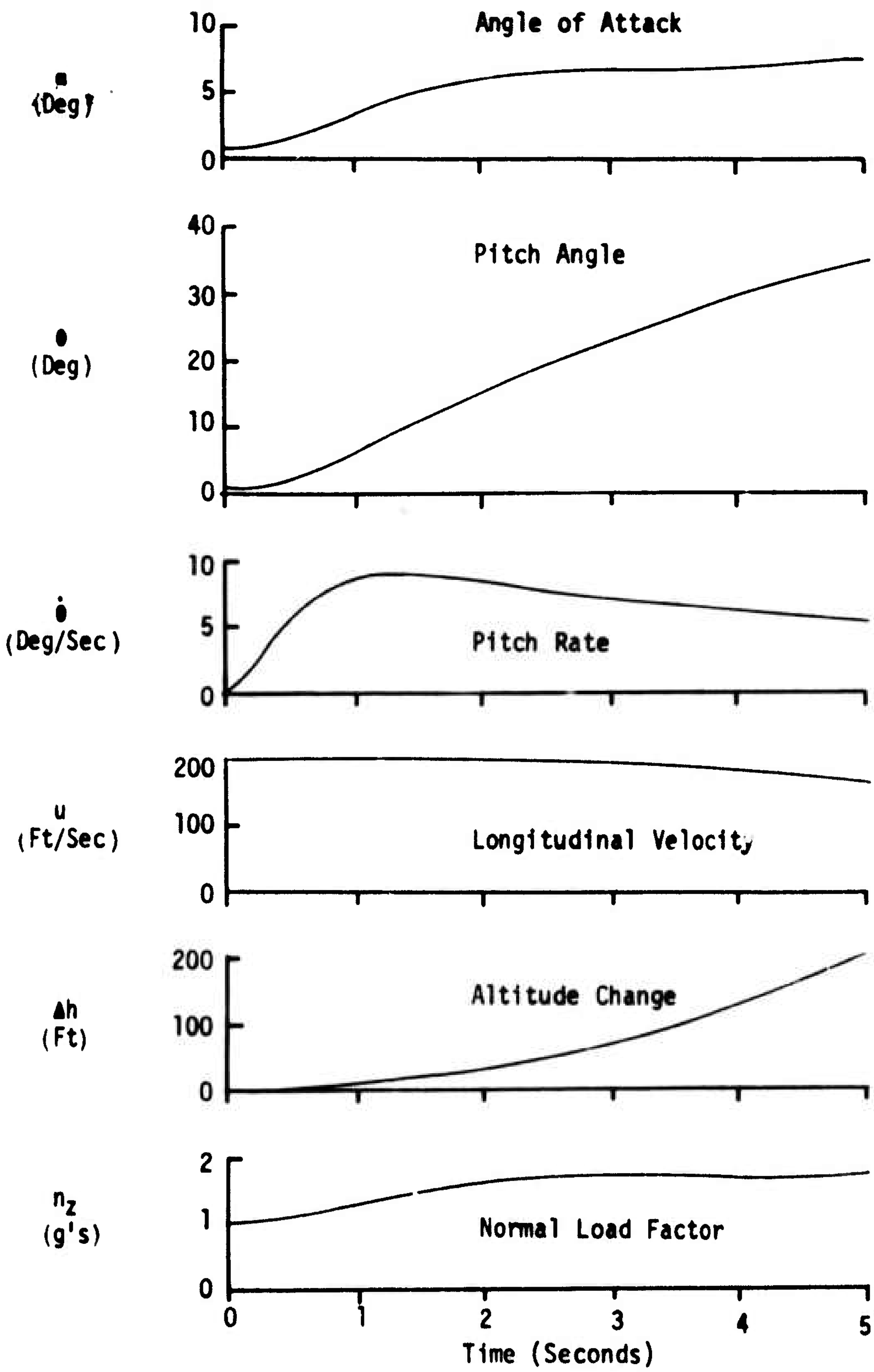


Figure 75. (U) Time History of Aircraft Motion Following the Air op of 6250 Pounds from Fuselage Station 220 – $i_w = 0^{\circ}$, $\delta_F = 30^{\circ}$.

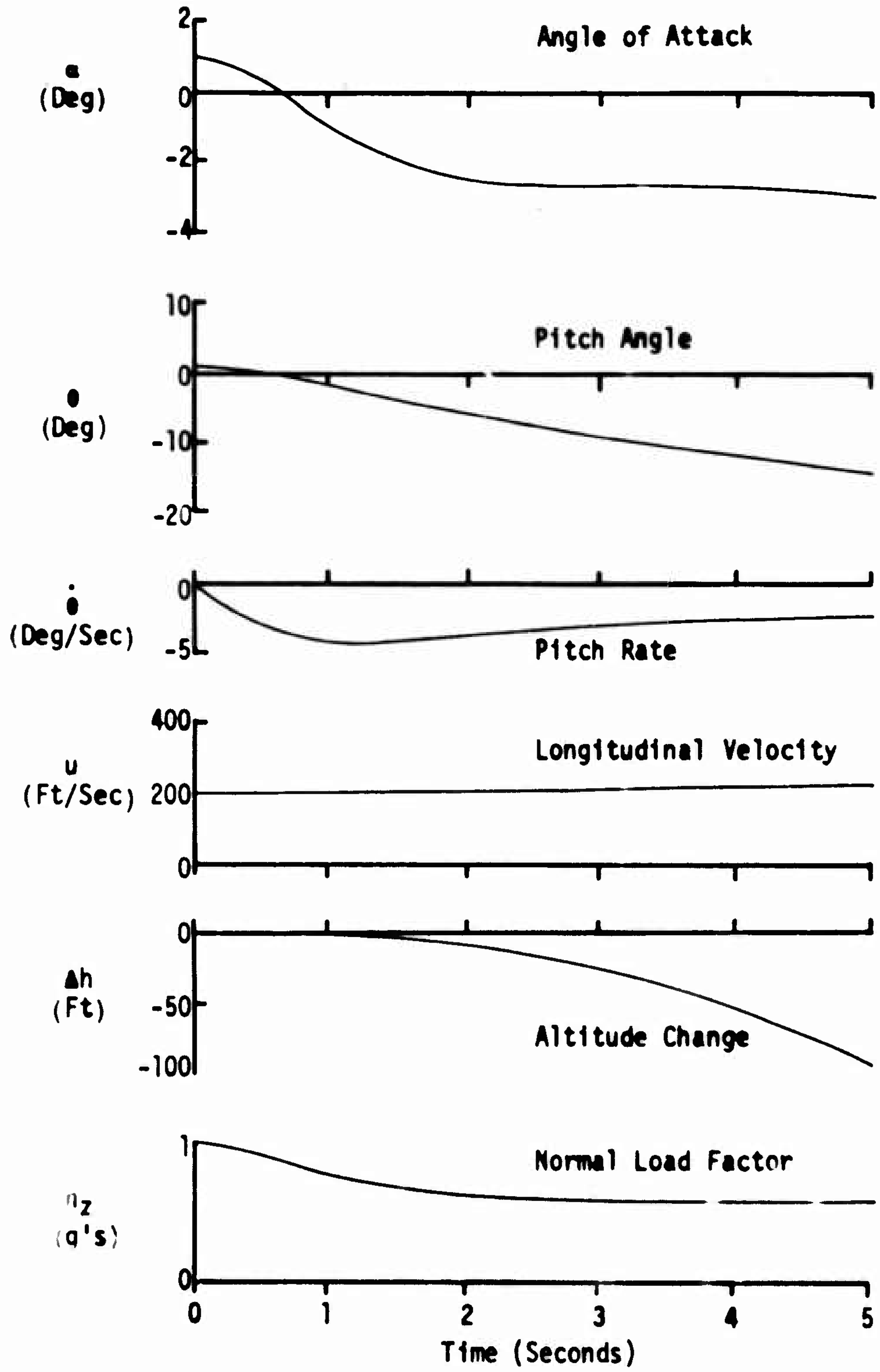


Figure 76. (U) Time History of Aircraft Motion Following the Airdrop of 700 Pounds from Fuselage Station 400 – $i_w = 0^\circ$, $\delta_F = 30^\circ$.

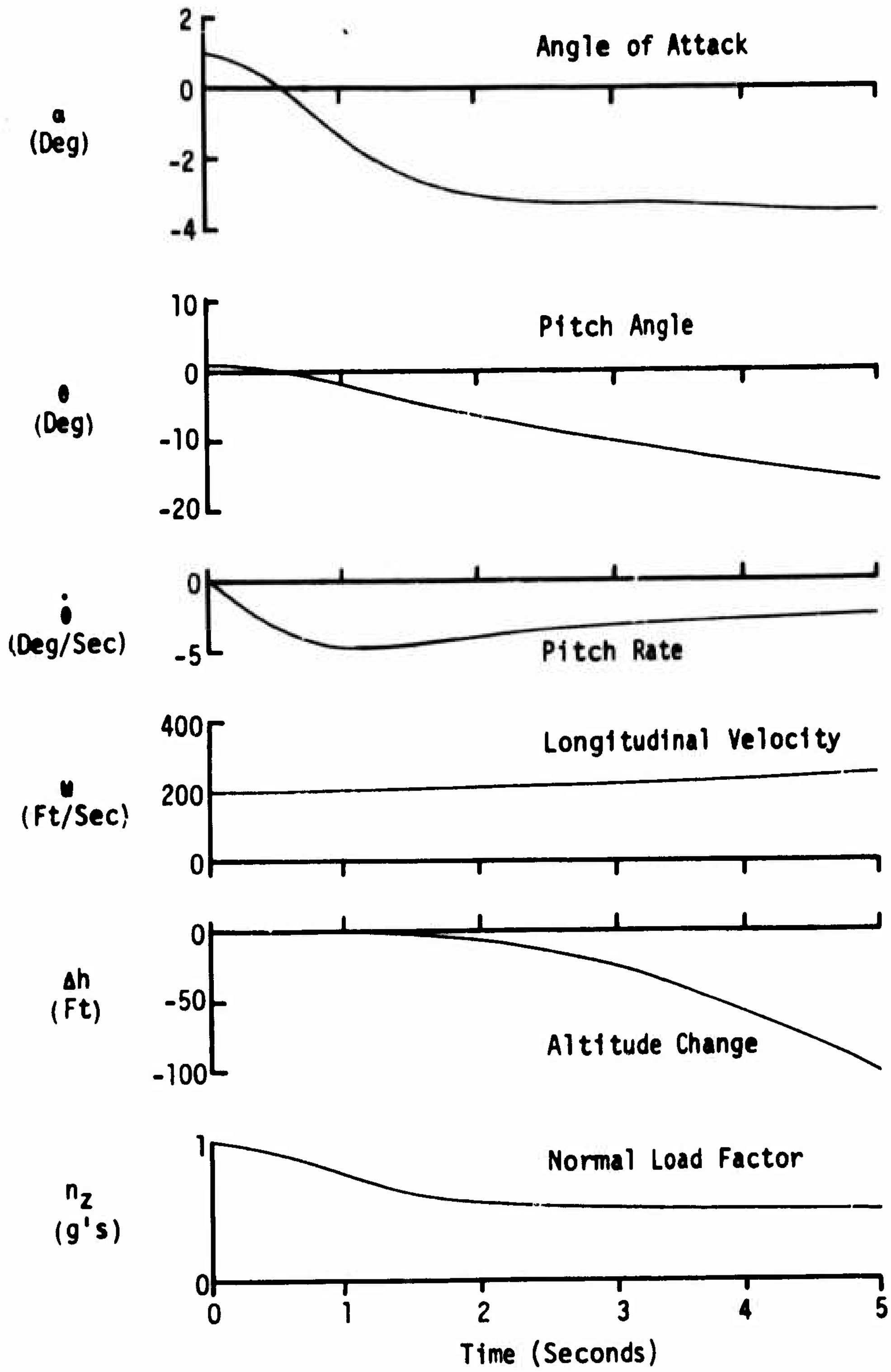


Figure 77. (U) Time History of Aircraft Motion Following the Airdrop of 1400 Pounds from Fuselage Station 340 – $i_w = 0^\circ$, $\delta_F = 30^\circ$.

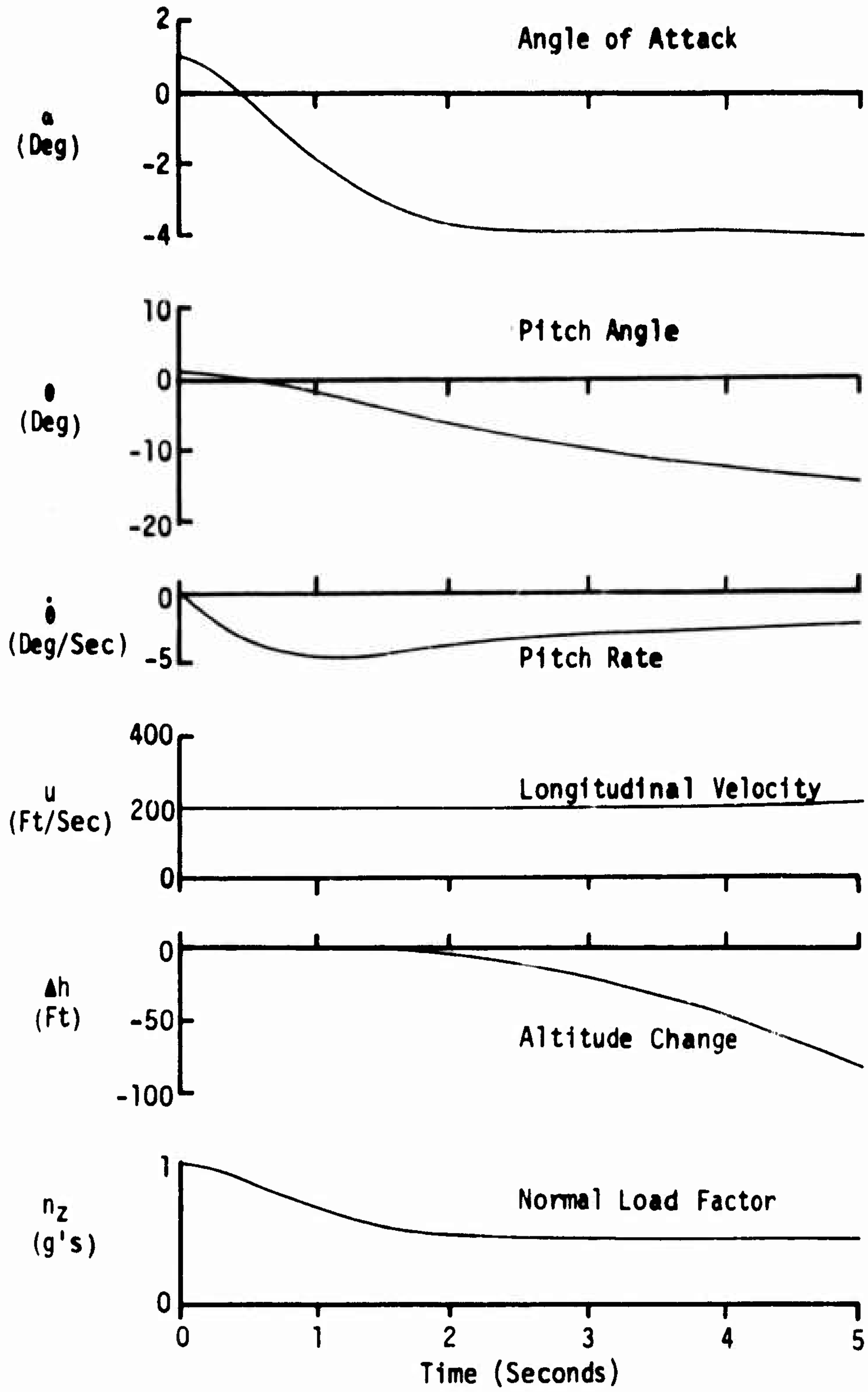


Figure 78. (U) Time History of Aircraft Motion Following the Airdrop of 4000 Pounds from Fuselage Station 280 – $i_w = 0^\circ$, $\delta_F = 30^\circ$.

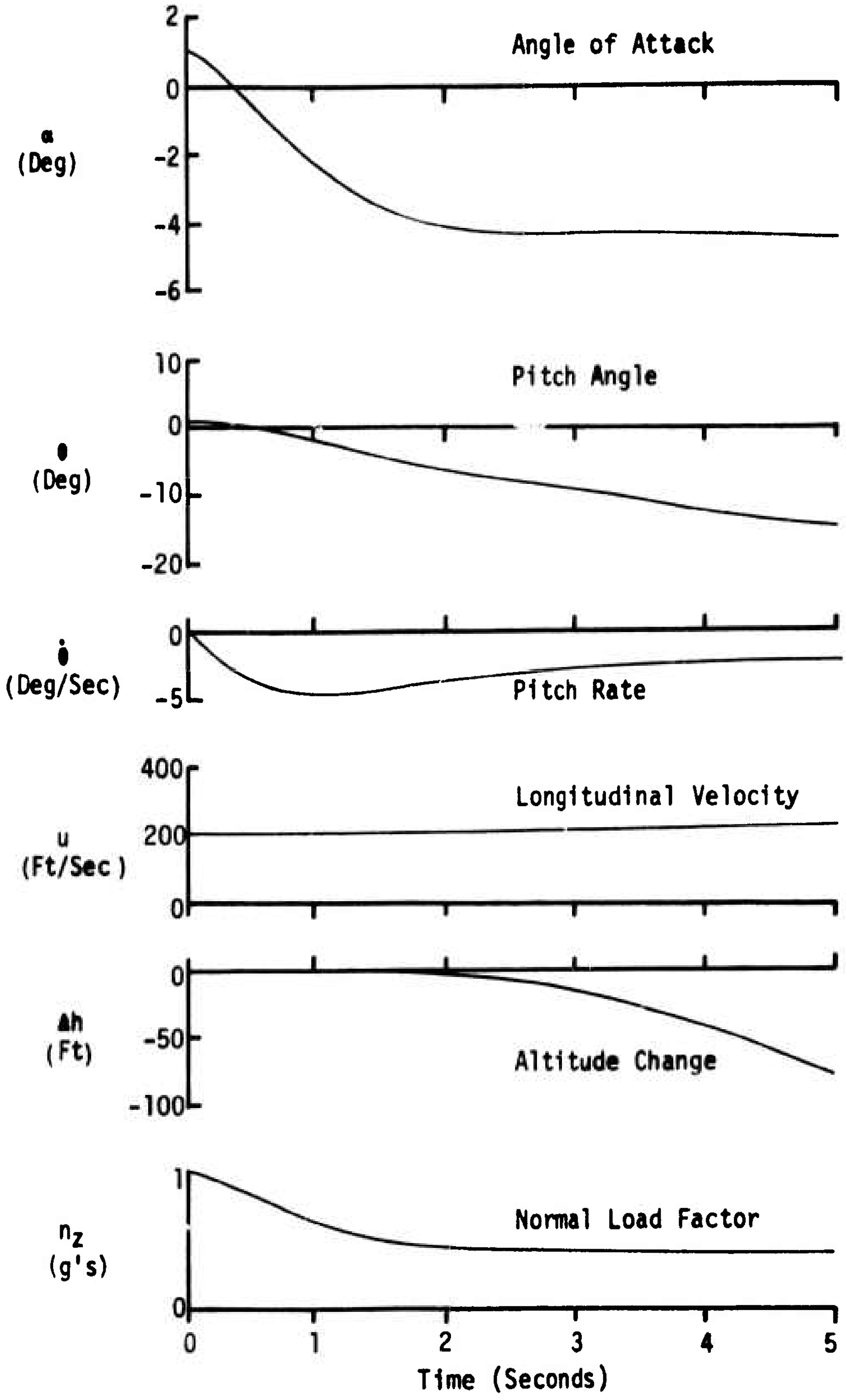


Figure 79. (U) Time History of Aircraft Motion Following the Airdrop of 5400 Pounds from Fuselage Station 280 – $i_w = 0^o$, $\delta_F = 30^o$.

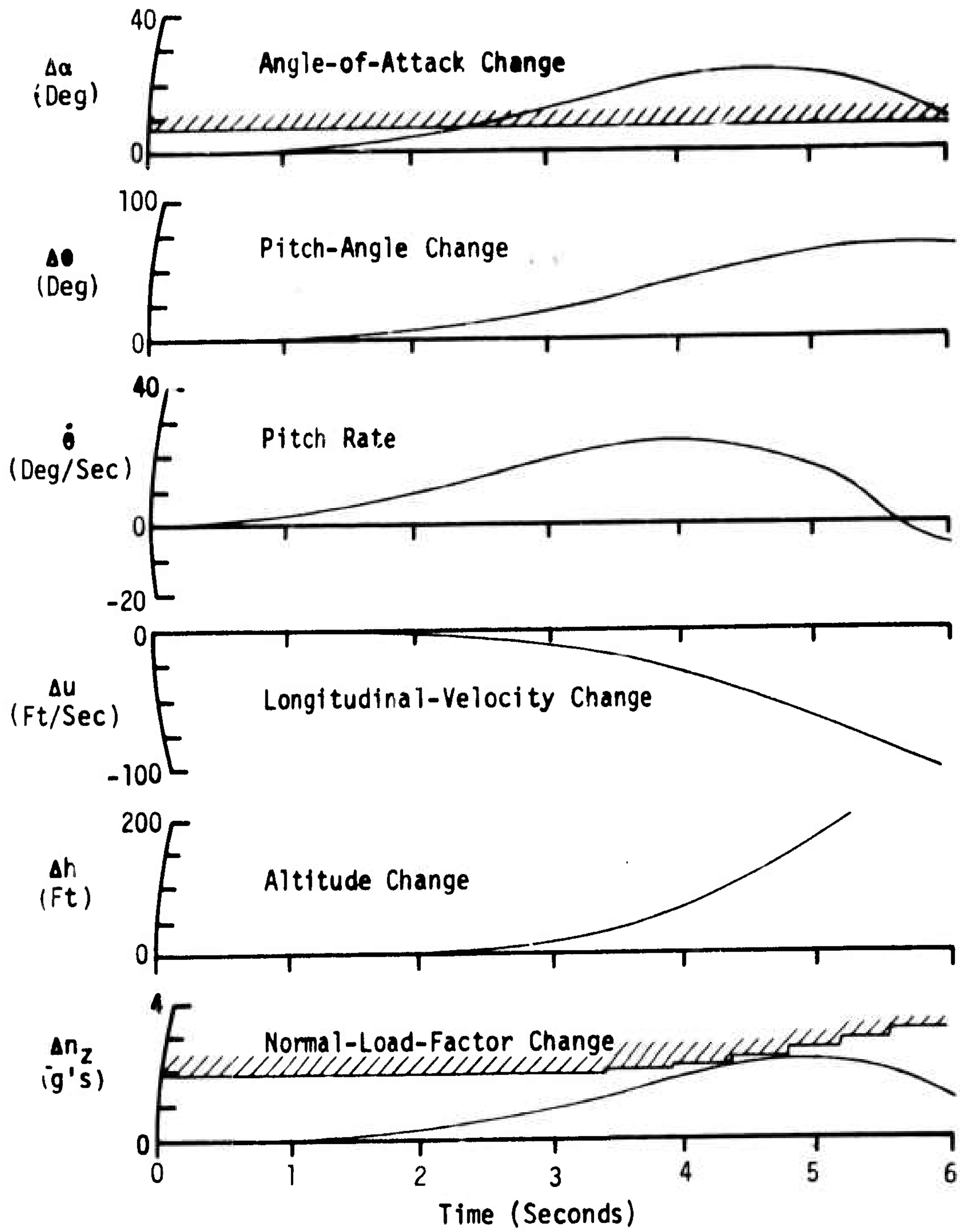


Figure 80. (U) Time History of Aircraft Motion Due to the Gravity Drop of Six A-22 Containers. No Stability Augmentation and $i_w = 0^o$, $\delta_F = 30^o$.

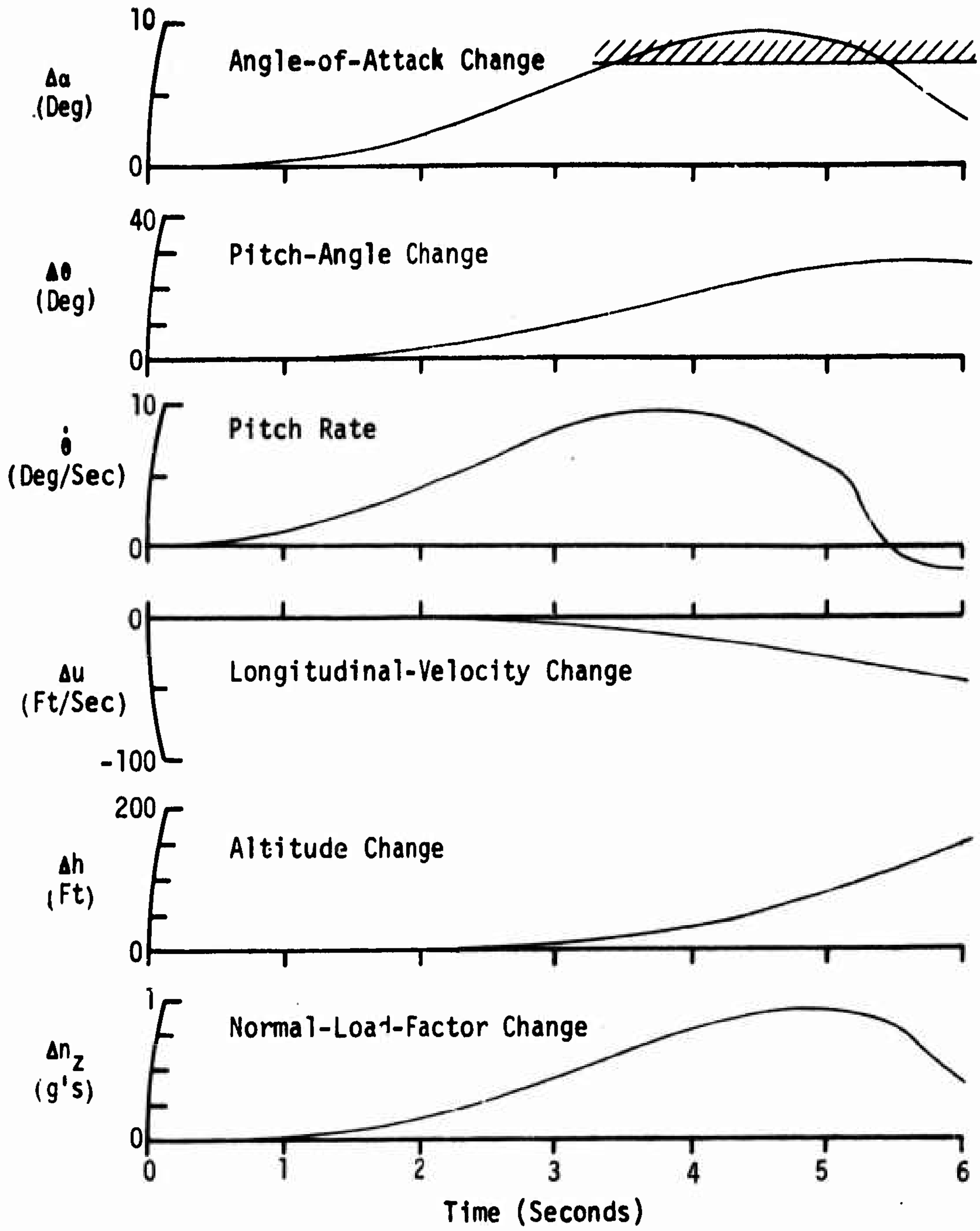


Figure 81. (U) Time History of Aircraft Motion Due to the Gravity Drop of Six A-22 Containers. Pitch Rate Damping and $i_w = 0^o$ and $\delta_F = 30^o$.

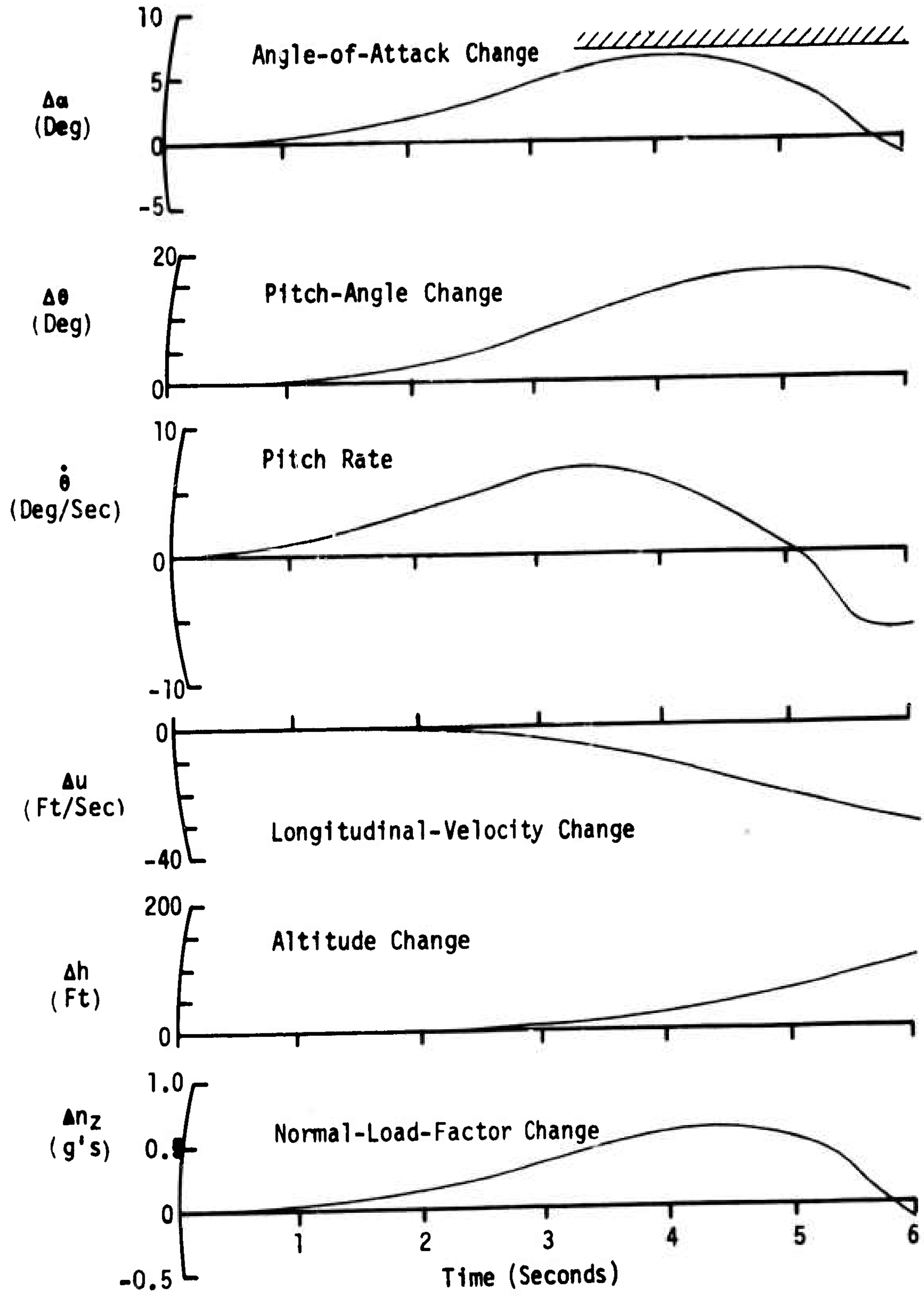


Figure 82. (U) Time History of Aircraft Motion Due to the Gravity Drop of Six A-22 Containers. Pitch Rate and Attitude Damping and $i_w = 0^o$, $\delta_F = 30^o$.

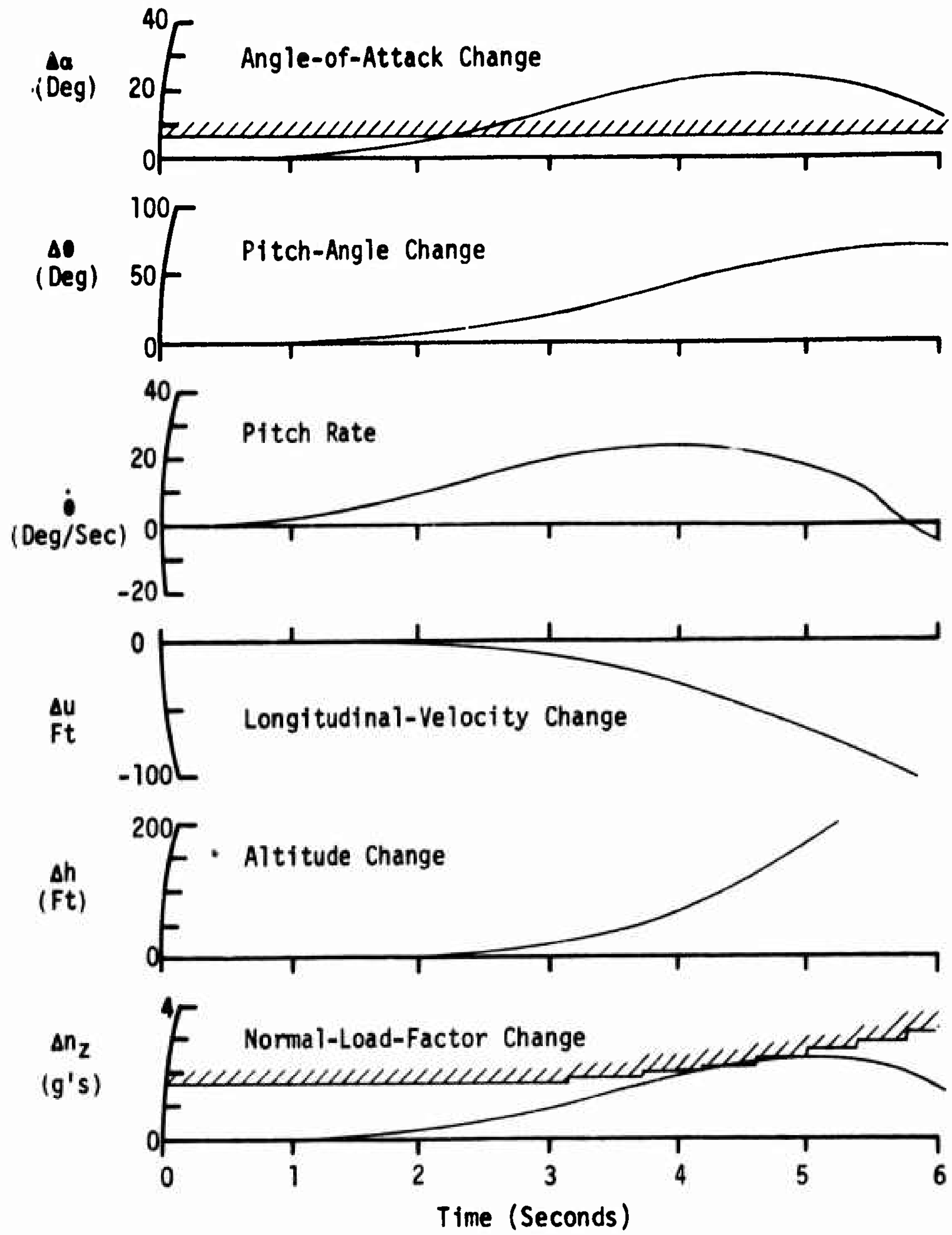


Figure 83. (U) Time History of Aircraft Motion Due to the Gravity Drop of Seven A-22 Containers. No Stability Augmentation and $i_w = 0^o$, $\delta_F = 30^o$.

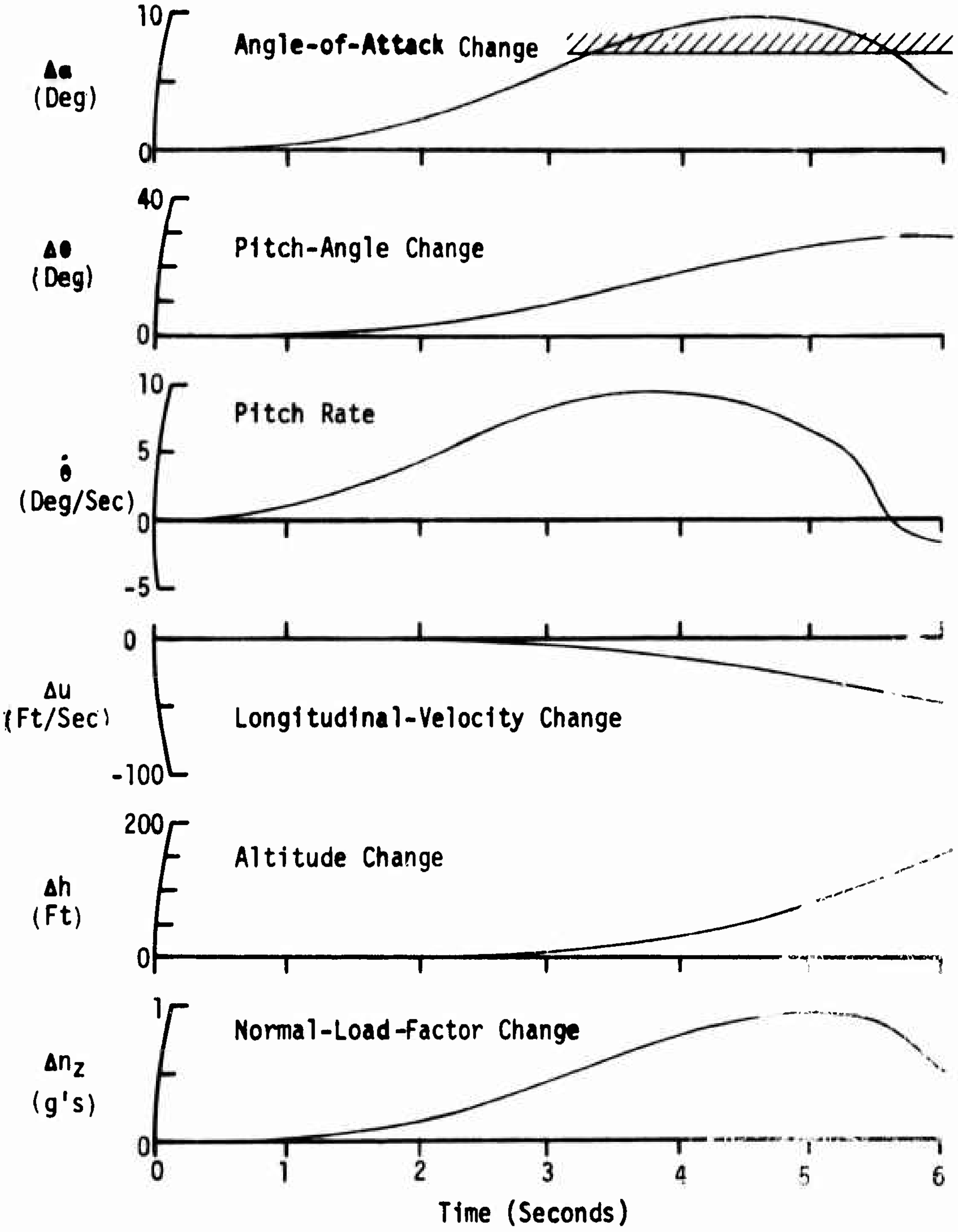


Figure 84. (U) Time History of Aircraft Motion Due to the Gravity Drop of Seven A-22 Containers. Pitch Rate Damping Augmentation and $i_w = 0^\circ$, $\delta_F = 30^\circ$.

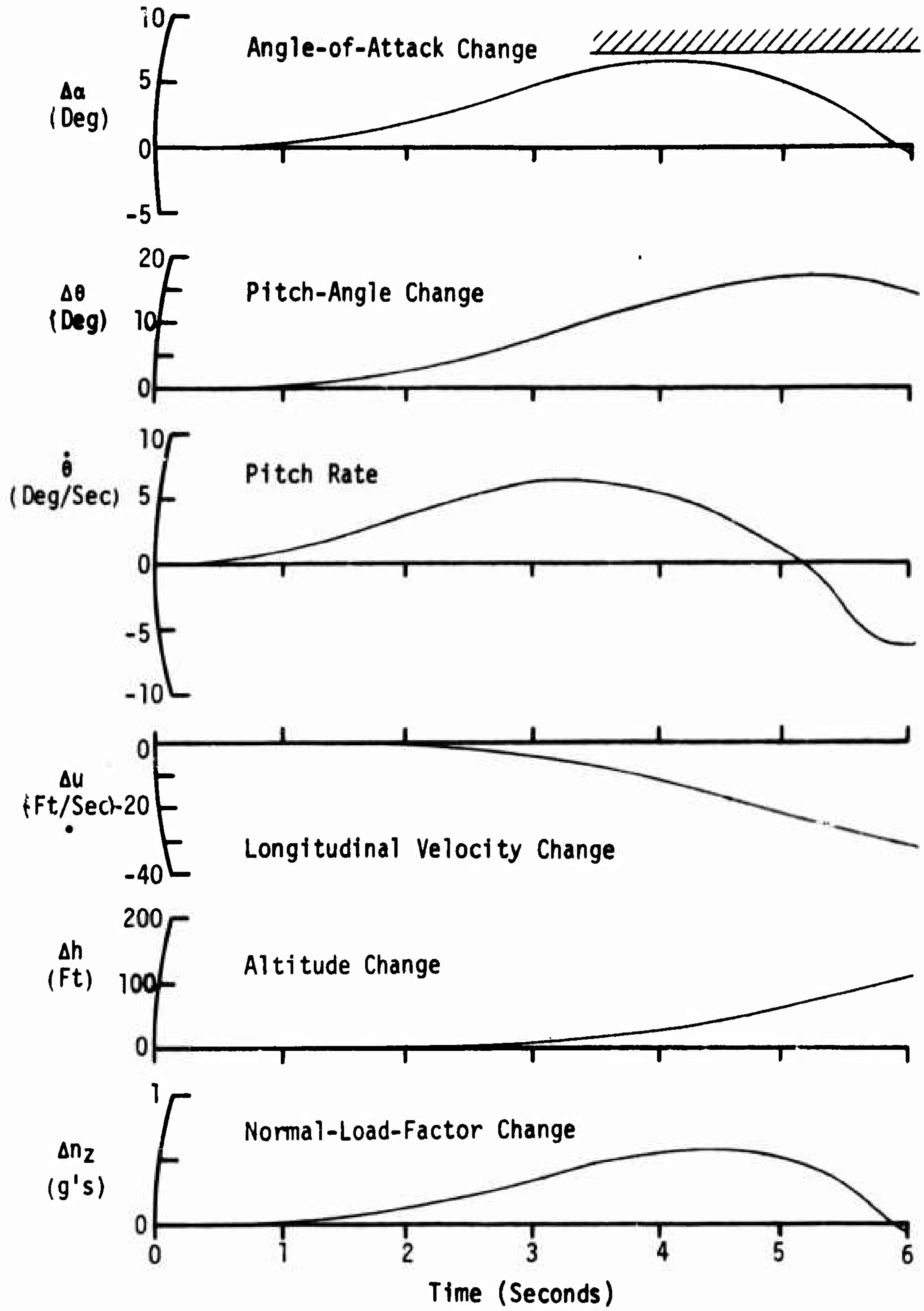


Figure 85. (U) Time History of Aircraft Motion Due to the Gravity Drop of Seven A-22 Containers. Pitch Rate Damping Augmentation and Attitude Hold and $i_w = 0^o$, $\delta_F = 30^o$.

(C) AERODYNAMIC PERFORMANCE COMPARISON (U)

(U) The primary mission of the model XC-142A assault aircraft is the transportation of combat troops, weapons and supplies in support of ground warfare. This chapter compares the effects of two different aerial cargo handling systems on the aerodynamic performance of the model XC-142A. Not all aerodynamic data is considered, but only that which is necessary in order to show the effects of the two systems on mission performance. The two systems considered and compared are a conventional cargo handling system and a vertical/modular cargo handling system. The comparison is made on the basis of five particular missions in an ICAO standard day environment. Effects of non-standard conditions are also discussed.

(U) PERFORMANCE DATA BASIS

All performance data used for this comparison is based on an ICAO standard day and is consistent with the "Utility Flight Manual" T. O. 1C-142(X)A dated 15 April 1966 (Reference 119), which incorporates all up-to-date flight test data. Fuel flow has been increased 5 percent for conservatism consistent with the data in T. O. 1C-142(X)A. The data considers use of the T64-GE-1 engine rated at 3080 SHP.

All recommended flight procedures and limitations specified in the "Utility Flight Manual" T. O. 1C-142(X)A have been followed. Any procedure or limitation which is not covered in T. O. 1C-142(X)A is allowed only after due consideration of the environment used for the XC-142A, and is subject to clearance from the Flight Manual Manager before actual operation.

(U) V/STOL

The XC-142A aircraft has the capability of tilting its wing from zero to approximately 98 degrees. Within this wing tilt range, three configurations are commonly referred to: conventional STOL configuration for wing tilt angles of from zero to 35 degrees; VTOL configuration for wing tilt angles of from 80 to 98 degrees; and the intermediate range between STOL and VTOL, which is referred to as a conversion or transition configuration. For the purposes of this chapter, use of VTOL, STOL, and conversion configuration will be used in conjunction with the above conditions.

(U) THRUST-TO-WEIGHT RATIO (T/W)

A minimum T/W of 1.10 is recommended by T. O. 1C-142(X)A for VTOL operation and is primarily dictated by single-engine failure capabilities. For the purposes of this study, a T/W of 1.10 is used to determine maximum weights for the VTOL flight.

(U) MISSION ENVIRONMENT AND OPERATING LIMITATIONS

If a mission comparison is made in light of both an operationally feasible environment and aircraft operating limitations, the result of those considerations is a strong foundation for completing a fair and operationally

valid comparison. While many considerations evolve from this type of approach to a comparison, some necessarily become redundant and therefore have no effect while others become vitally important and form the basis for mission definition.

For the purposes of this comparison, the environment of Vietnam is chosen for the XC-142A. Vietnam is considered to have an atmospheric and terrain environment at least as unfavorable, to an aircraft, as that found in 80 percent of the world, and is an existing terrain and atmosphere for actual ground warfare and its support by assault cargo aircraft.

The cruise altitude region used in this comparison is determined by two considerations. The minimum cruise altitude is determined by consideration of small-arms ground fire capabilities. There exists some altitude at which this type of enemy defense becomes ineffective and gives the aircraft negligible vulnerability. The maximum cruise altitude is determined by consideration of operational altitude envelopes used by combat aircraft. There exist some altitudes at which a transport aircraft would interfere with combat aircraft operations.

The XC-142A cruise altitude region, determined by the above considerations, was found to be higher than 2500 feet and lower than 5000 feet above the terrain. Since cruise fuel consumption decreases with an increase in altitude, a cruise altitude of 5000 feet is chosen to take advantage of better cruise fuel consumption.

A minimum hovering altitude of 5 feet above the terrain was used for the mission comparison. This altitude provides for XC-142A hovering operation out of ground effect and out of the recirculation region, and also is compatible with the altitude chosen for a hover cargo delivery mode after consideration of cargo damage due to a free-fall drop.

Airdrop altitudes were chosen after consideration of parachute performance and were determined to be 1500 feet above the terrain for the vertical/ modular system and 1250 feet above the terrain for the conventional system.

Cruise speeds used for the mission comparison were determined by analyzing the effect of cruise speed on productivity. Productivity is one measure of aircraft effectiveness and is defined as payload delivered per cycle time. For the purposes of this chapter, all performance was compared at conditions for maximum productivity, which was determined by analysis to be maximum continuous power airspeed. (This assumed two engines and four propellers operating as recommended by T. O. 1C-142 (X)A for low altitude cruise.) This condition for maximum productivity is also verified by LTV Report No. 2-55400/5R-2218 (Reference 33, page 32). An inherent benefit of this speed is a decrease in aircraft vulnerability.

All hover flight, conversions and reconversions are to be conducted at 95 percent propeller set RPM, and assumes 100 percent average torque.

The maximum landing gross weight is 41,500 pounds at 11.5 feet/second sink rate. This limitation provides a maximum landing weight for STOL landings.

The maximum takeoff gross weight is 41,500 pounds at the design limit, but strength is provided for higher weights, providing the product of weight and load factor remains constant. Therefore, if the allowable load factor is reduced to 2.5g from 2.7g, the maximum STOL takeoff gross weight is 43,700 pounds, which is also the maximum flight design gross weight. This restriction also will determine takeoff payload after takeoff fuel load is determined.

The maximum weight when taxiing over uneven surfaces is 41,500 pounds and would be a limiting factor on takeoff and landing weight when operating out of unimproved airfields. For the purposes of this report, all airfields at the origin are considered improved and those at the destination are considered unimproved. Therefore, this restriction is assumed to apply only at the destination, where the aircraft is already limited to a maximum STOL landing weight of 41,500 pounds and to a maximum VTOL landing weight determined by a T/W of 1.10. At the mission origin, maximum weights are determined by aerodynamic restrictions.

The maximum airspeed for airdrop is 125 knots.

(U) WEIGHT DATA

The weights for the loading conditions used for this comparison are based on LTV Report No. 2-53310/4R942, "Performance Data Report", Model XC-142A, dated 13 May 1964 (Reference 16, page 184), and are consistent with T.O. 1C-142(X)A. Weights are derived in Table XXVIII.

TABLE XXVIII (U)
WEIGHT DERIVATION

ITEM	WEIGHT POUNDS
Weight Empty	23,926
Basic Items	
Pilots	430
Crew Chief	215
Unusable Fuel	35
Unusable Oil	70
Usable Oil	80
XC-142A Takeoff Weight (Less Fuel and Payload)	24,756
Additional Weight Increment for Conventional Delivery System	+ 734
Additional Weight Increment for Vertical/Modular Delivery System	+ 1523

(U) DRAG DATA

The drag data used for this comparison is consistent with that contained in Reference 16. For the purposes of this comparison, no drag increment was added for either the conventional system or the vertical/modular system, although it is realized that the vertical/modular system would entail redesign of the main gear wheel well fairing and a possible change in wetted area.

(U) FUEL QUANTITY DATA

The maximum usable internal JP-4 fuel capacity was set at 9100 pounds of fuel and is consistent with T. O. 1C-142(X)A and Reference 16.

(U) TAKEOFF ALLOWANCE AND LANDING RESERVES

MIL-C-5011A, Military Specification Charts: Standard Aircraft Characteristics and Performance, Piloted Aircraft, dated 5 November 1951, does not define fuel allowances and reserve for takeoff and landing of a VTOL/STOL aircraft.

For STOL takeoff and landings, MIL-C-5011A is used as the basis for the fuel allowances and reserve used for the comparison, except that landing reserves used for a STOL landing at the origin are 10 percent of the initial fuel instead of the defined 5 percent plus 30 minutes loiter. It should be noted here that this reserve is consistent with that defined in MIL-C-5011A for a helicopter.

Since takeoff allowances and landing reserves using the VTOL configuration are not defined in MIL-C-5011A, these allowances and reserves have been determined by the contractor and are defined in the mission description.

(U) MISSION DESCRIPTION AND RESULTS

The following graphs present the results of the mission comparison, assuming an ICAO standard day and observing the previously discussed limitations. For convenience, each graph presents aerodynamic data for both cargo handling systems applied to a given mission. The necessary aerodynamic data consists of payload versus radius, fuel used versus radius, engine time versus radius. and cruise speed versus radius.

STOL/STOL MISSION

1. Warm-up, taxi, STOL takeoff and accelerate to climb speed. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

2. Climb on course with four-engine military rated power to cruise altitude.

3. Shut down two engines.

4. Cruise out at two-engine normal rated power at cruise altitude.

5. Land STOL at destination (no fuel used).

6. Shut down all engines.

7. Unload 100 percent of initial payload.

8. Load 25 percent of initial payload.

9. Warm-up, taxi, STOL takeoff and accelerate to climb speed. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

10. Climb on course with four-engine military rated power to cruise altitude.

11. Shut down two engines.

12. Cruise back at two-engine normal rated power at cruise altitude.

13. Land STOL at origin (no fuel used).

14. Landing reserves — 10 percent of initial fuel.

STOL/VTOL MISSION

1. Warm-up, taxi, STOL takeoff and accelerate to climb speed. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

2. Climb on course with four-engine military rated power to cruise altitude.

3. Shut down two engines.

4. Cruise out at two-engine normal rated power at cruise altitude.

5. Land VTOL at destination. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

6. Shut down all engines.

*7. Sequence for Step 7 is according to number of stops (see below).

8. Warm-up, VTOL takeoff and accelerate to climb speed. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

9. Climb on course with four-engine military rated power to cruise altitude.

10. Shut down two engines.

11. Cruise back at two-engine normal rated power at cruise altitude.

12. Land STOL at origin (no fuel used).

13. Landing reserves — 10 percent of initial fuel.

*Sequence According to Number of Stops

One Stop

1. Unload 100 percent of initial payload.

2. Load 25 percent of initial payload.

3. Go to Step 8 in Mission Description.

Two Stops

1. Unload 50 percent of initial payload at first stop.

2. Warm-up, VTOL takeoff and accelerate to climb speed. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

3. Move aircraft to second stop 10 nautical miles away. Fuel allowance is 115 pounds.

4. Land VTOL at second stop. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

5. Shut down all engines.

6. Unload 50 percent of initial payload.

7. Load 25 percent of initial payload.

8. Go to Step 8 in Mission Description.

Three Stops

1. Unload 33-1/3 percent of initial payload at first stop.

2. Warm-up, VTOL takeoff and accelerate to climb speed. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

3. Move aircraft to second stop 10 nautical miles away. Fuel allowance is 115 pounds.

4. Land VTOL at second stop. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

5. Shut down all engines.

6. Unload 33-1/3 percent of initial payload at second stop.

7. Warm-up, VTOL takeoff and accelerate to climb speed. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

8. Move aircraft to third stop 10 nautical miles away. Fuel allowance is 115 pounds.

9. Land VTOL at third stop. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

10. Shut down all engines.

11. Unload 33-1/3 percent of initial payload at third stop.

12. Load 25 percent of initial payload.

13. Go to Step 8 in Mission Description.

(See Figures 86 through 89)

STOL/AIRDROP MISSION

1. Warm-up, taxi, STOL takeoff and accelerate to climb speed. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

2. Climb on course with four-engine military rated power to cruise altitude.

3. Shut down two engines.

4. Cruise out at two-engine normal rated power at cruise altitude.

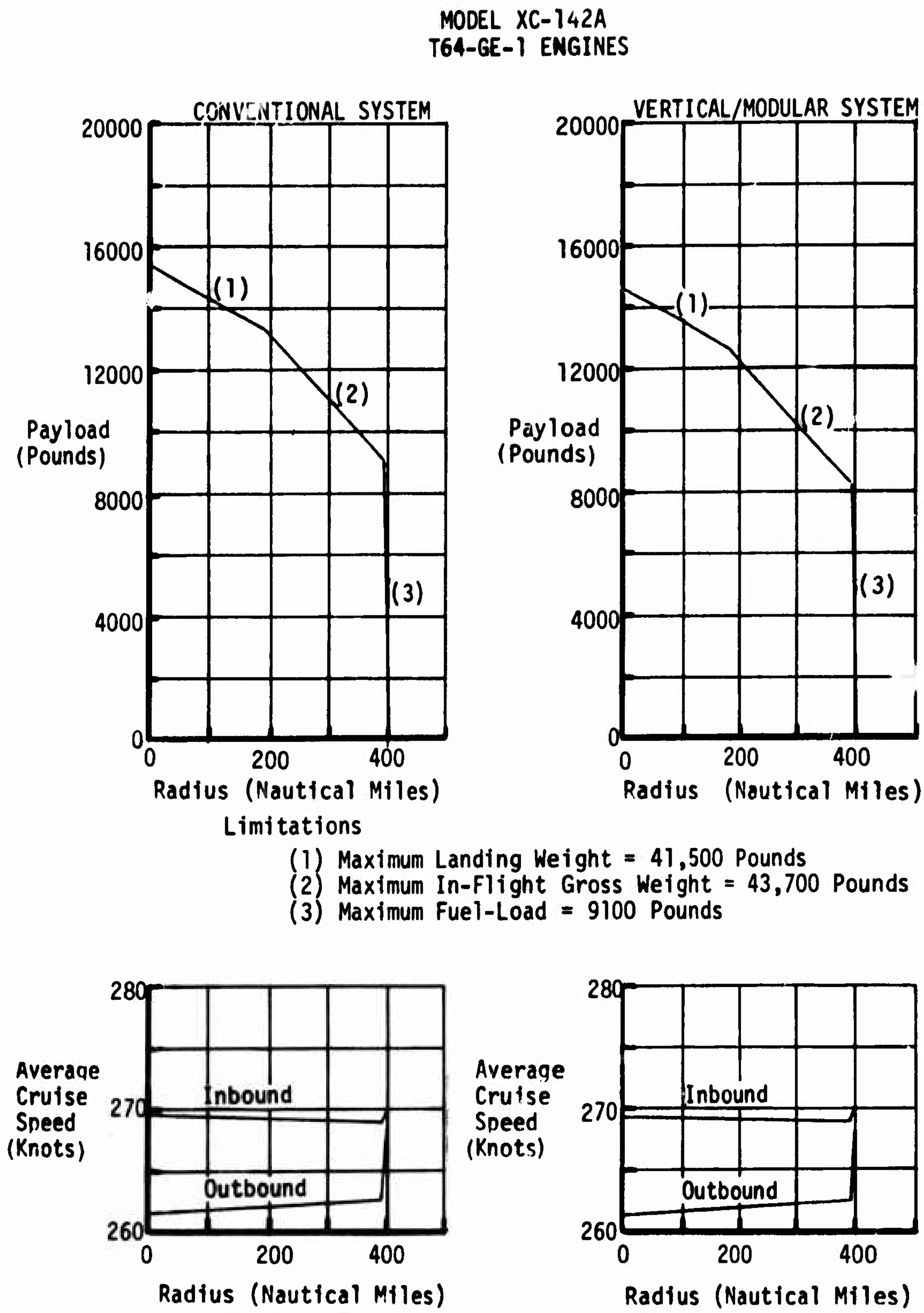


Figure 86. (U) Payload and Average Cruise Speed versus Radius. STOL/STOL Mission with Conventional and Vertical/Modular Cargc Delivery System.

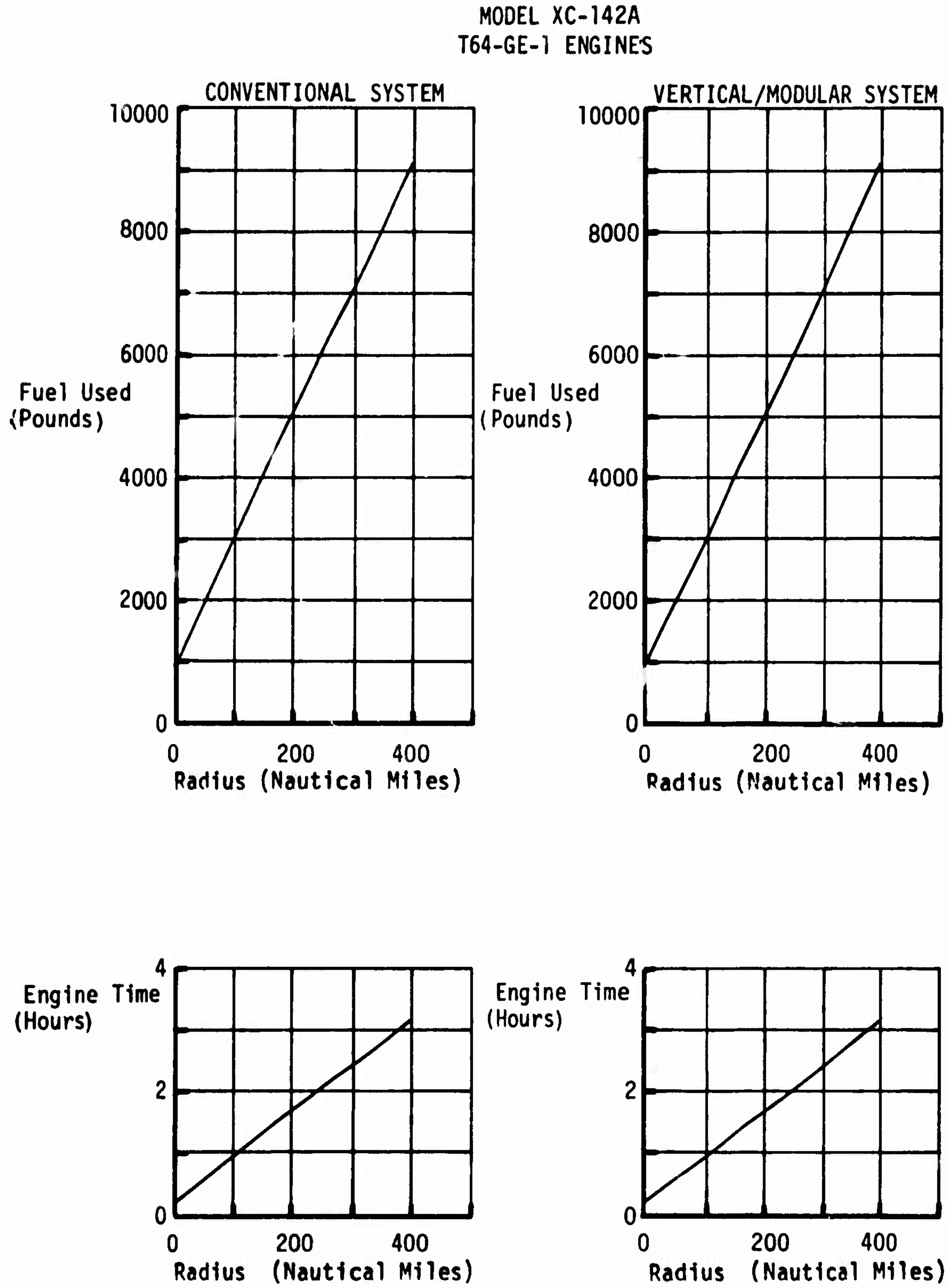


Figure 87. (U) Fuel Used and Engine Time versus Radius. STOL/STOL Mission with Conventional and Vertical/Modular Cargo Delivery System.

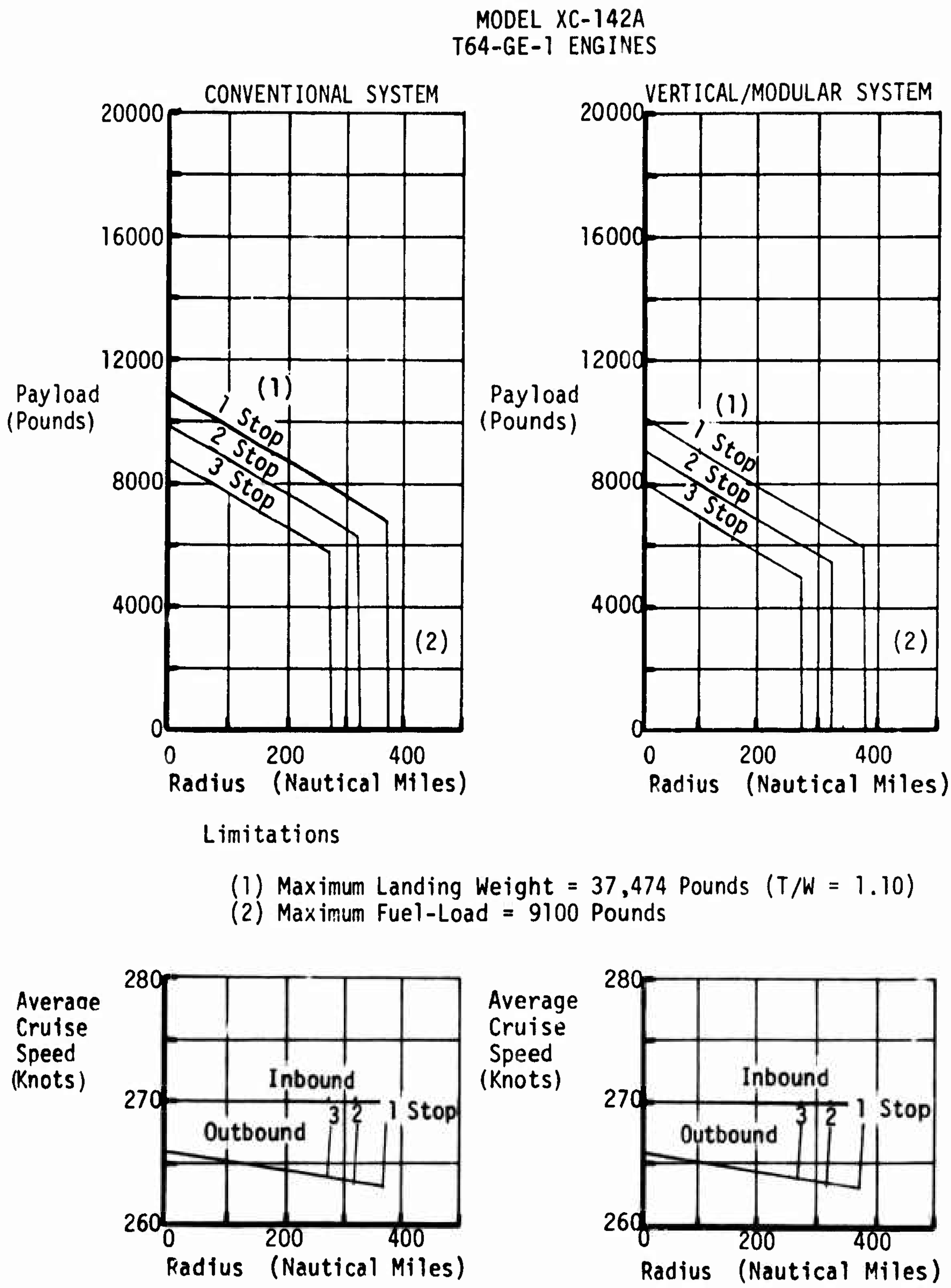


Figure 88. (U) Payload and Average Cruise Speed versus Radius. STOL/VTOL Mission Conventional and Vertical/Modular Cargo Delivery System.

MODEL XC-142A
T64-GE-1 ENGINES

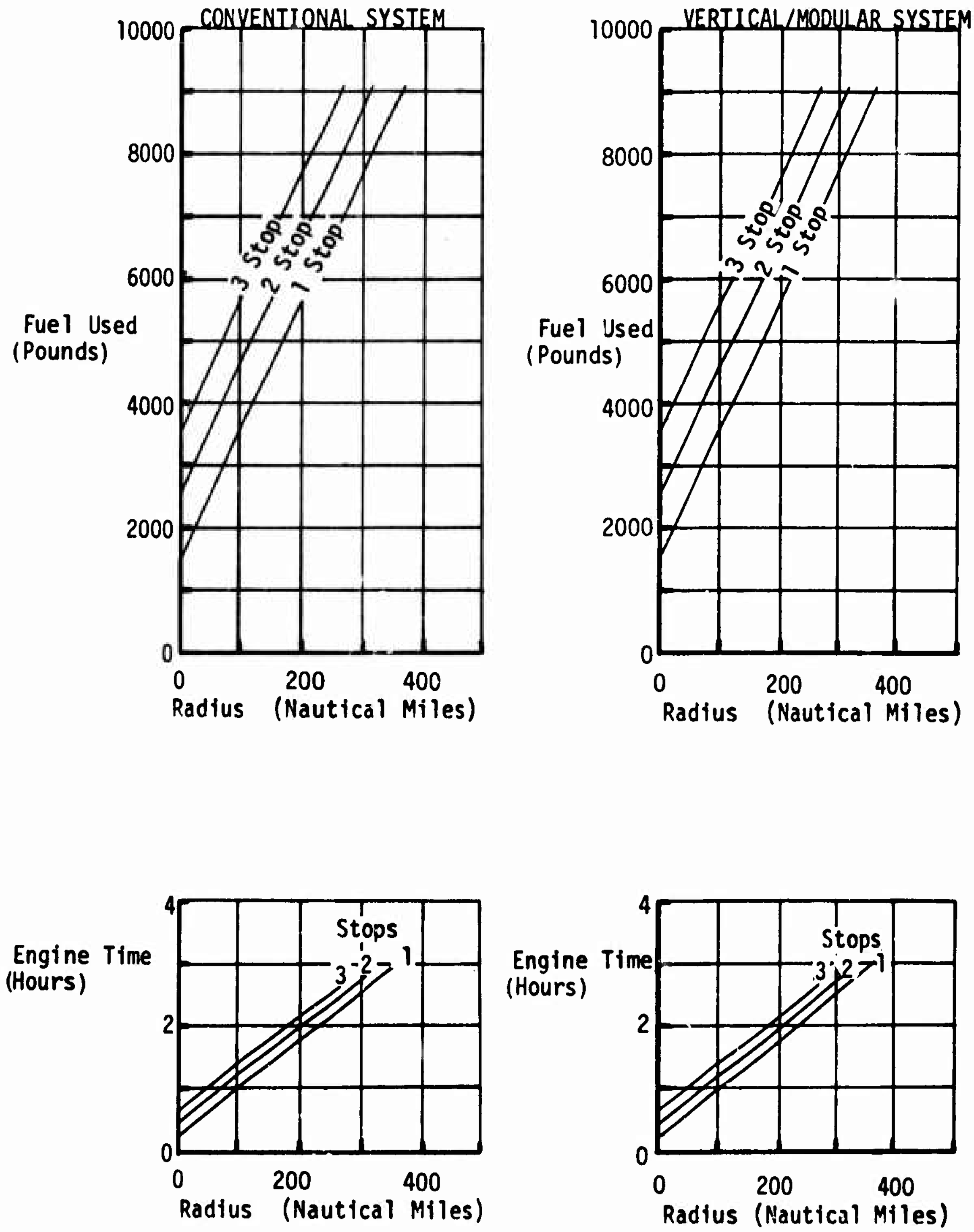


Figure 89. (U) Fuel Used and Engine Time versus Radius. STOL/VTOL Mission with Conventional and Vertical/Modular Cargo Delivery System.

5. Descend to airdrop altitude.

6. Airdrop 100 percent of initial payload at 125 knots. Fuel allowance is 5 minutes with two engines operating at 125 knots at airdrop altitude.

7. Climb on course with four-engine military rated power to cruise altitude.

8. Shut down two engines.

9. Cruise back at two-engine normal rated power at cruise altitude.

10. Land STOL at origin (no fuel used).

11. Landing reserves — 10 percent of initial fuel.

VTOL/VTOL MISSION

1. Warm-up, VTOL takeoff and accelerate to climb speed. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

2. Climb on course with four-engine military rated power to cruise altitude.

3. Shut down two engines.

4. Cruise out at two-engine normal rated power at cruise altitude.

5. Land VTOL at destination.

6. Shut down all engines.

7. Unload 100 percent of initial payload.

8. Load 25 percent of initial payload.

9. Warm-up, VTOL takeoff and accelerate to climb speed. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

10. Climb on course with four-engine military rated power to cruise altitude.

11. Shut down two engines.

12. Cruise back at two-engine normal rated power at cruise altitude.

13. Land VTOL at origin.

14. Landing reserve — 10 percent of initial fuel.

STOL/HOVER MISSION

1. Warm-up, taxi, STOL takeoff and accelerate to climb speed. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

2. Climb on course with four-engine military rated power to cruise altitude.

3. Shut down two engines.

4. Cruise out at two-engine normal rated power at cruise altitude.

*5. Sequence for Step 5 is according to number of stops (see below).

6. Climb on course with four-engine military rated power to cruise altitude.

7. Shut down two engines.

8. Cruise back at two-engine normal rated power at cruise altitude.

9. Land STOL at origin (no fuel used).

10. Landing reserves — 10 percent of initial fuel.

*Sequence According to Number of Stops

One Stop

1. Hover for 5 minutes, release 100 percent of initial payload. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

2. Go to Step 6 in Mission Description.

Two Stops

1. Hover for 5 minutes and release 50 percent of initial payload at first stop. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

2. Move aircraft to second stop 10 nautical miles away. Fuel allowance is 115 pounds.

3. Hover for 5 minutes and release 50 percent of initial payload at second stop. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

4. Go to Step 6 in Mission Description.

Three Stops

1. Hover for 5 minutes and release 33-1/3 percent of initial payload at first stop. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

2. Move aircraft to second stop 10 nautical miles away. Fuel allowance is 115 pounds.

3. Hover for 5 minutes and release 33-1/3 percent of initial payload at second stop. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

4. Move aircraft to third stop 10 nautical miles away. Fuel allowance is 115 pounds.

5. Hover for 5 minutes and release 33-1/3 percent of initial payload at third stop. Fuel allowance is 5 minutes at four-engine normal rated sea level static power.

6. Go to Step 6 in Mission Description.

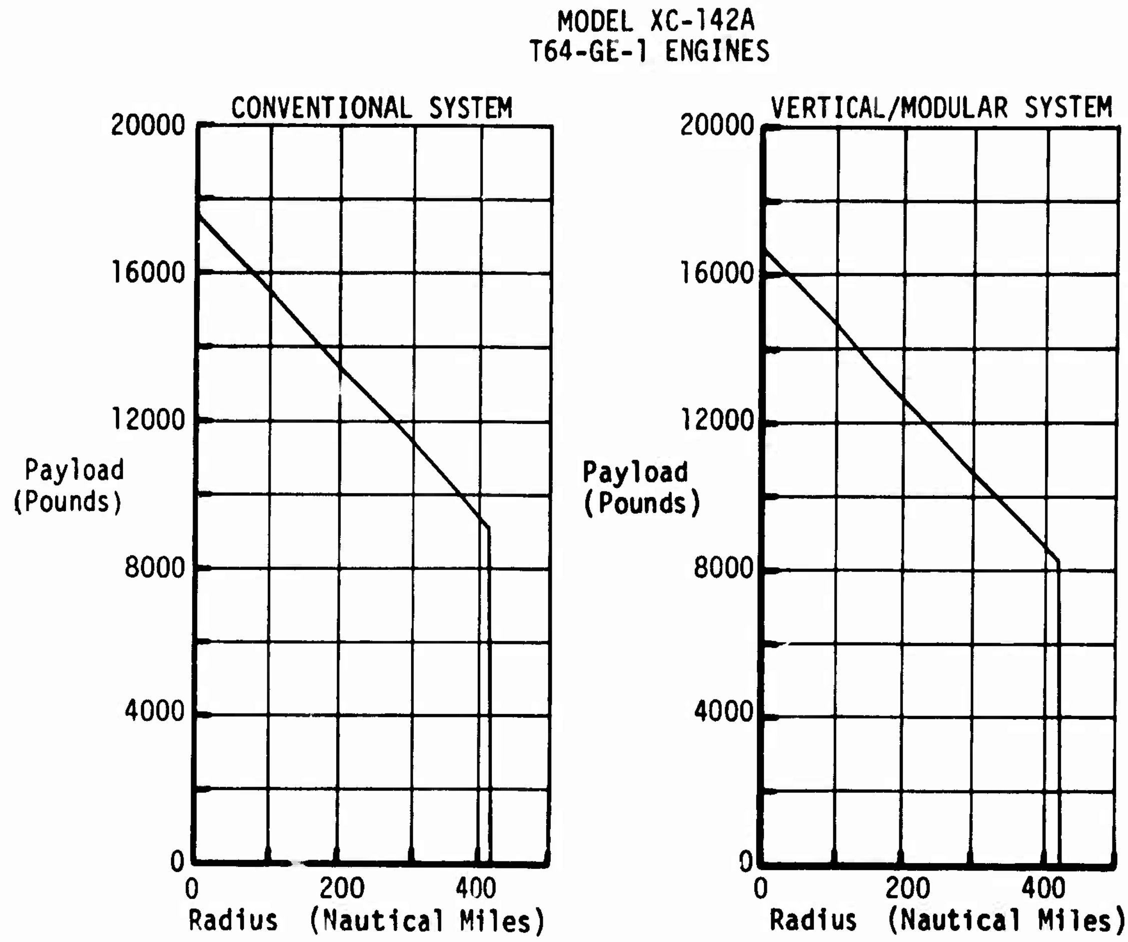
(Reference Figures 90 through 95)

(C) EFFECTS OF NON-STANDARD CONDITIONS (U)

(C) Two non-standard day temperature/altitude conditions were also studied for this comparison: 87°F/sea level; and 83°F/2000 feet. Calculations showed the percentage increase in true airspeed over that of an ICAO day, listed in Table XXIX. Specific range can be assumed not to vary from an ICAO standard day.

TABLE XXIX (C)
NON-STANDARD TRUE AIRSPEEDS (U)

Temperature/Altitude °F/Feet	% Increase in True Airspeeds
87/Sea Level	2.8
83/2000	3.7



Limitations

(1) Maximum In-Flight Gross Weight - 43,700 pounds
(2) Maximum Fuel-Load = 9100 Pounds

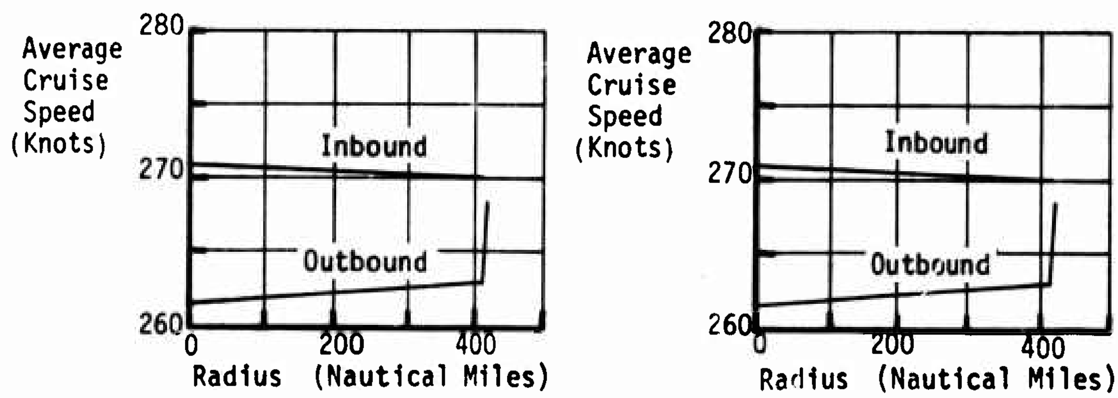


Figure 90. (U) Payload and Average Cruise Speed versus Radius. STOL/ Airdrop Mission with Conventional and Vertical/Modular Cargo Delivery System.

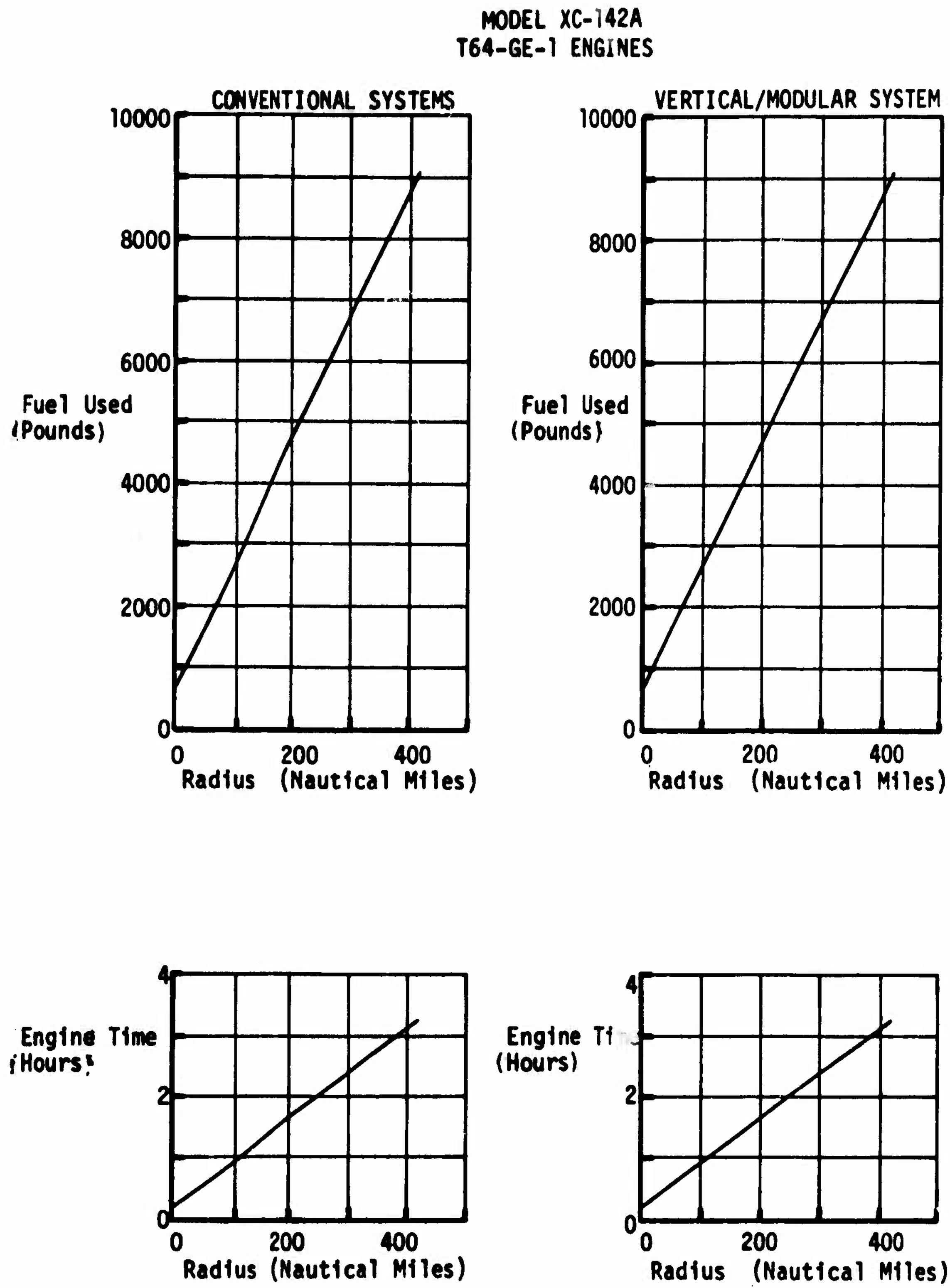


Figure 91. (U) Fuel Used and Engine Time versus Radius. STOL/AIRDROP Mission with Conventional and Vertical/Modular Cargo Delivery System.

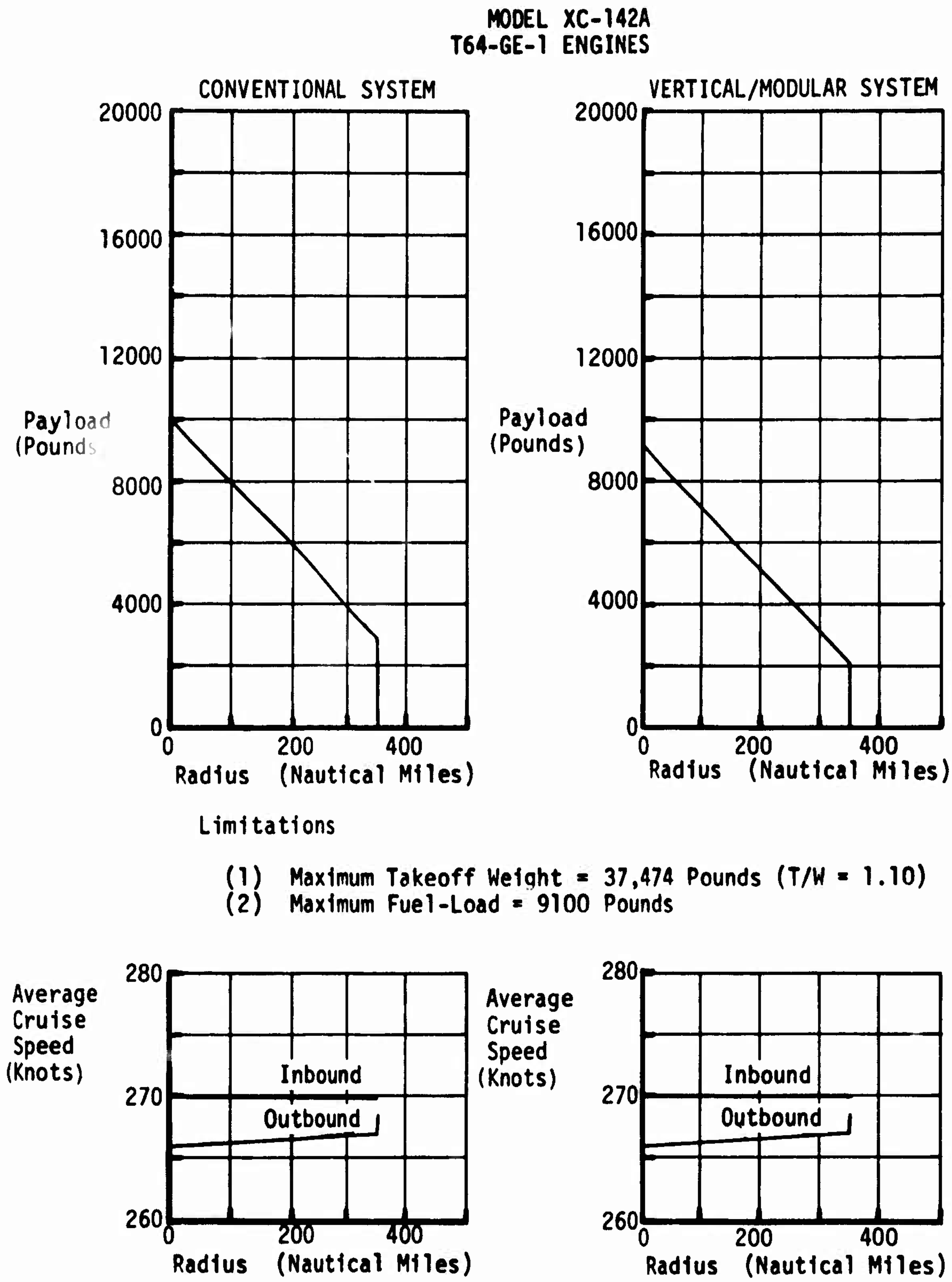


Figure 92. (U) Payload and Average Cruise Speed versus Radius. VTOL/VTOL Mission with Conventional and Vertical/Modular Cargo Delivery System.

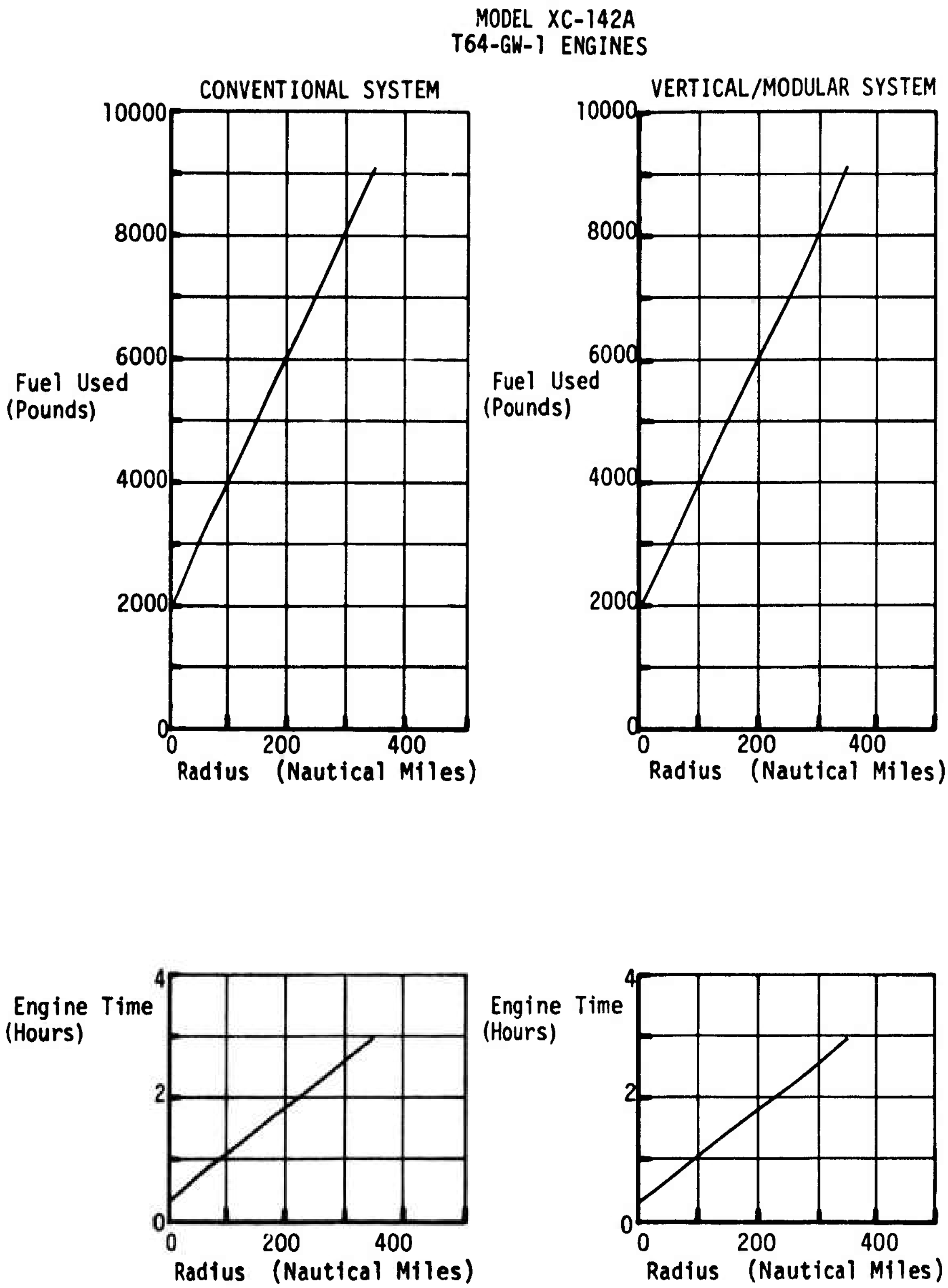


Figure 93. (U) Fuel Used and Engine Time versus Radius. VTOL/VTOL Mission with Conventional and Vertical/Modular Cargo Delivery System.

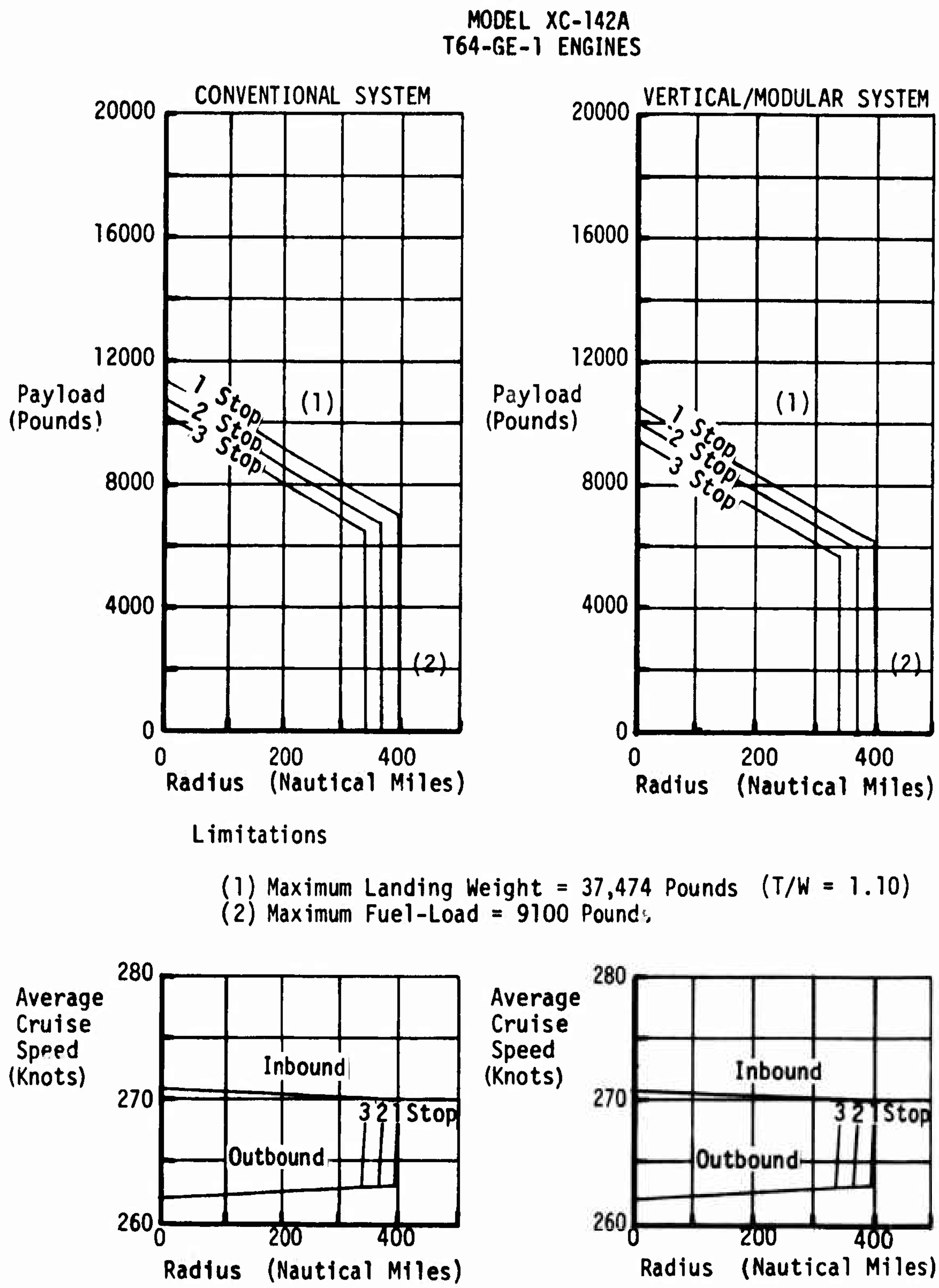


Figure 94. (U) Payload and Average Cruise Speed versus Radius. STOL/HOVER Mission with Conventional and Vertical/Modular Cargo Delivery System.

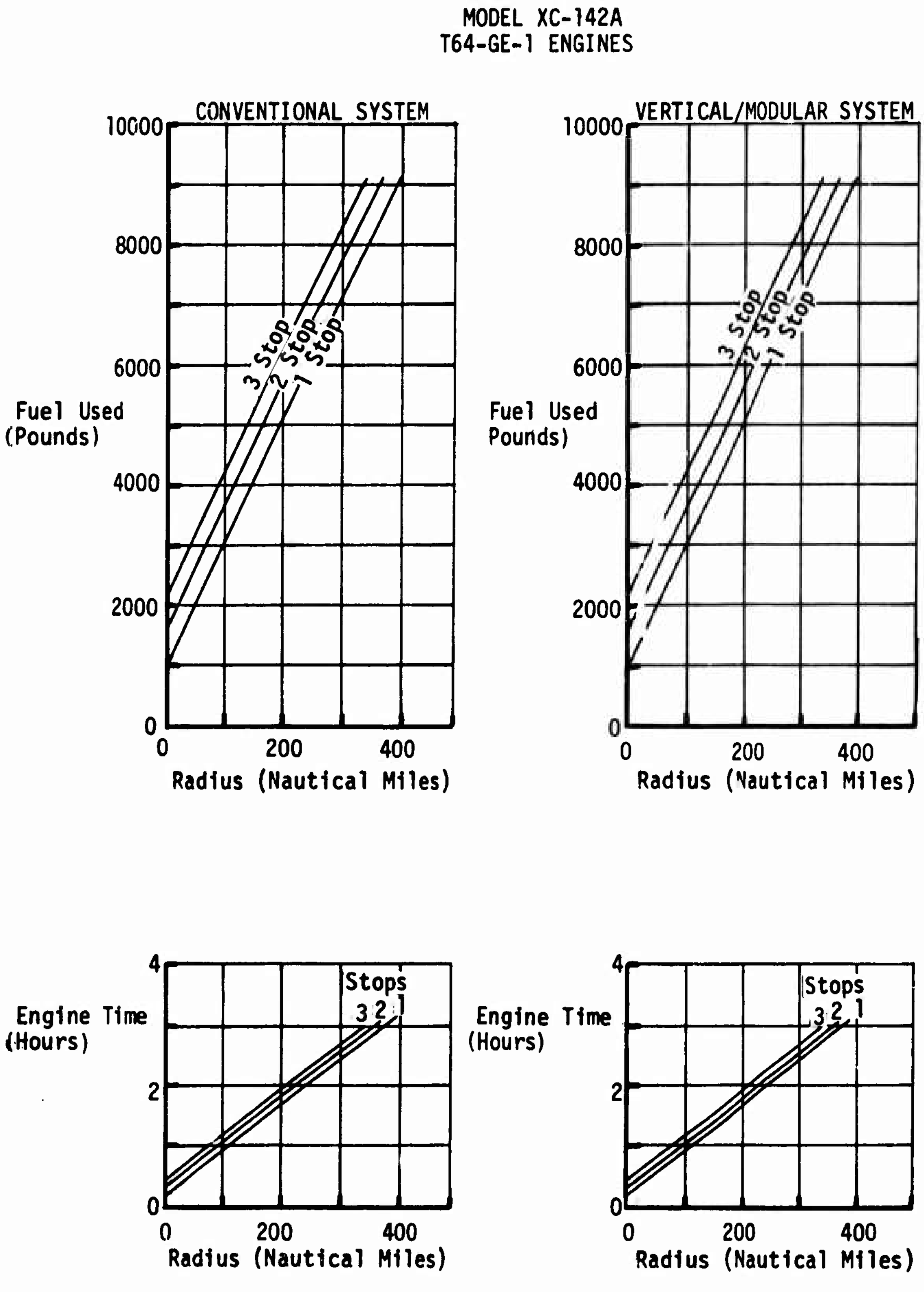


Figure 95. (U) Fuel Used and Engine Time versus Radius. STOL/HOVER Mission with Conventional and Vertical/Modular Cargo Delivery System.

(U) Humidity effects are known to be minor as shown in NACA TN 2119 (Reference 63, page 11), which in summary says: "The humidity effect on [cruise] performance was small. Experimental results showed that thrust was affected most and that for a given engine speed this parameter decreased 3.6 percent for a variation in specific humidity from 30 to 210 grains of water per pound of dry air." The saturation specific humidity at sea level on a standard day occurs when 75 grains of water per pound of dry air are present.

(U) Due to the effects of temperature and altitude on thrust, T/W as it affects maximum VTOL takeoff and landing weights was found to be the primary factor governing mission performance. When hover flight is desired at the destination, T/W determines maximum VTOL weight as shown in Figure 96. The difference between maximum VTOL weight and zero payload weight will then determine available payload.

(C) Three missions were affected by non-standard day conditions: STOL/VTOL; VTOL/VTOL; and STOL/Hover. For these missions and a T/W of 1.10, the change in payload from 59°F/sea level to 87°F/sea level was a negative 1200 pounds and was constant with radius due to the same cruising altitude. The change in payload from 59°F/sea level to 83°F/2000 feet was a negative 2650 pounds at zero radius and a negative 2400 pounds at 300 nautical miles with a linear variation in between. This variation was due to a higher cruising altitude and the associated better fuel consumption.

(U) MINIMUM THRUST-TO-WEIGHT RATIO

The minimum T/W ratio for XC-142A VTOL operation has been established by flight test as 1.10 (Reference 119). This will allow for recovery of the aircraft in case of a single engine failure from any altitude except as shown in Figure 97. XC-142A VTOL single-engine failure effects shown in Figure 98 are redrawn from T.O. IC-142(X)A. When VTOL operation is required to reach the delivery site, because of natural obstacles (trees, hills, rough terrain, etc.), the area of particular interest is at or near 90° wing incidence angle and the "avoid" operation area must be flown through.

The conventional cargo delivery system must operate within the T/W = 1.10 limitation. The vertical/modular cargo delivery system has the capability of increasing the T/W ratio, while airborne, by dropping cargo. Procedure to accomplish this would be to: open the bottom doors under selected cargo modules as the VTOL descent is begun, descend to approximately 20 feet, close doors during descent from 20 to 10 feet, and VTOL land. If the flight plan calls for a hover drop, the doors would not be closed. In this configuration the selected cargo modules can be dropped if the emergency loss of an engine occurs above 30 feet. Thus, although thrust is decreased, weight is also decreased and the net T/W ratio would remain constant or increase, depending on the amount of cargo dropped.

A more detailed analysis, beyond the scope of this study, would be required to determine exact minimum T/W ratios; however, preliminary investigations indicate that the vertical/modular system would permit a four-engine T/W below 1.10. The "avoid" operation envelope could be reduced or

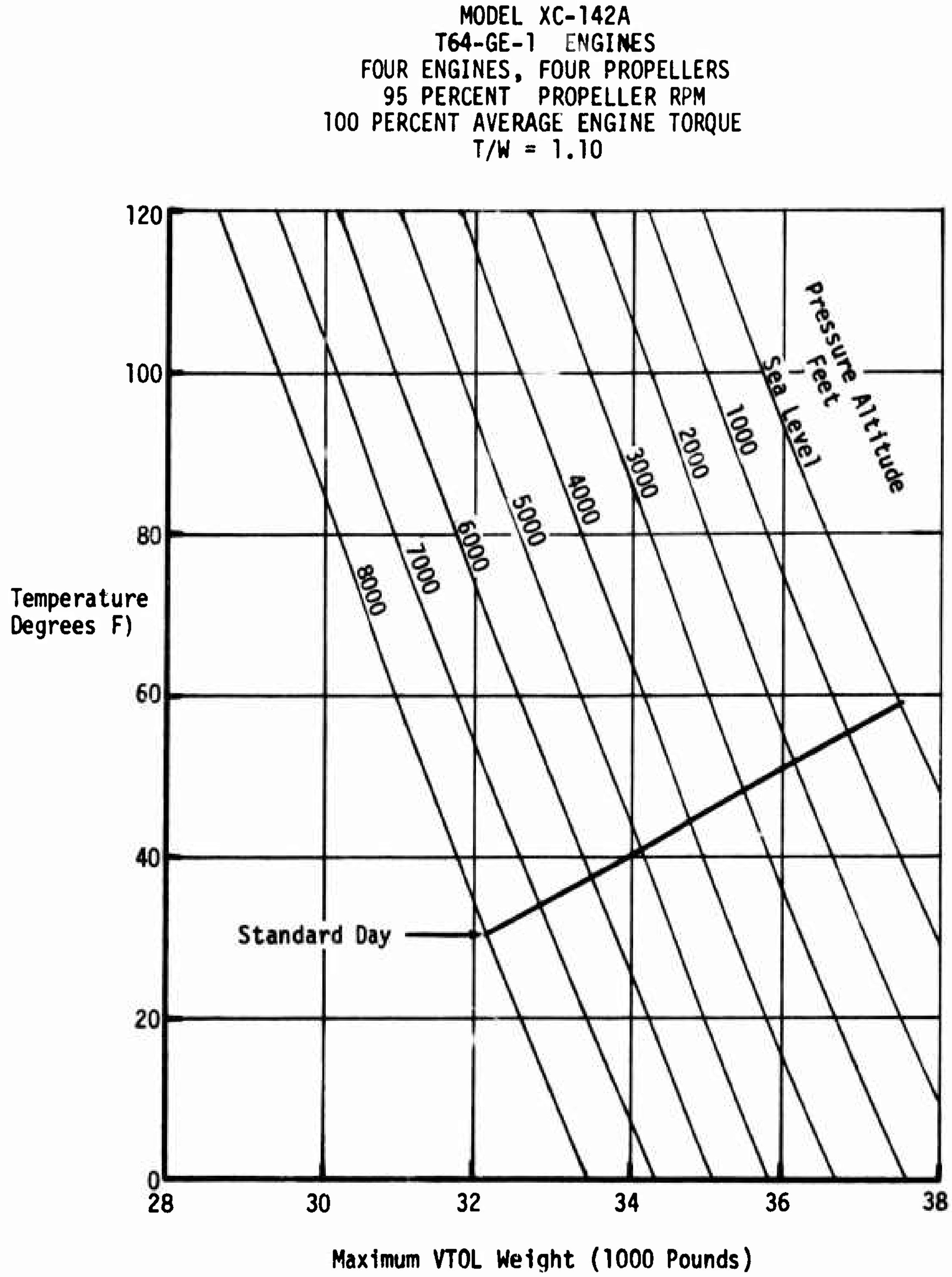


Figure 96. (U) Hover Performance Out of Ground Effect.

MODEL XC-142A
T64-GE-1 ENGINES

Initial Conditions

1. Four-Engine T/W = 1.10
2. Unaccelerated Fuselage Level Flight
3. Zero Rate of Descent
4. Two-Second Reaction Time Delay
5. Ninety-Five-Percent Propeller RPM

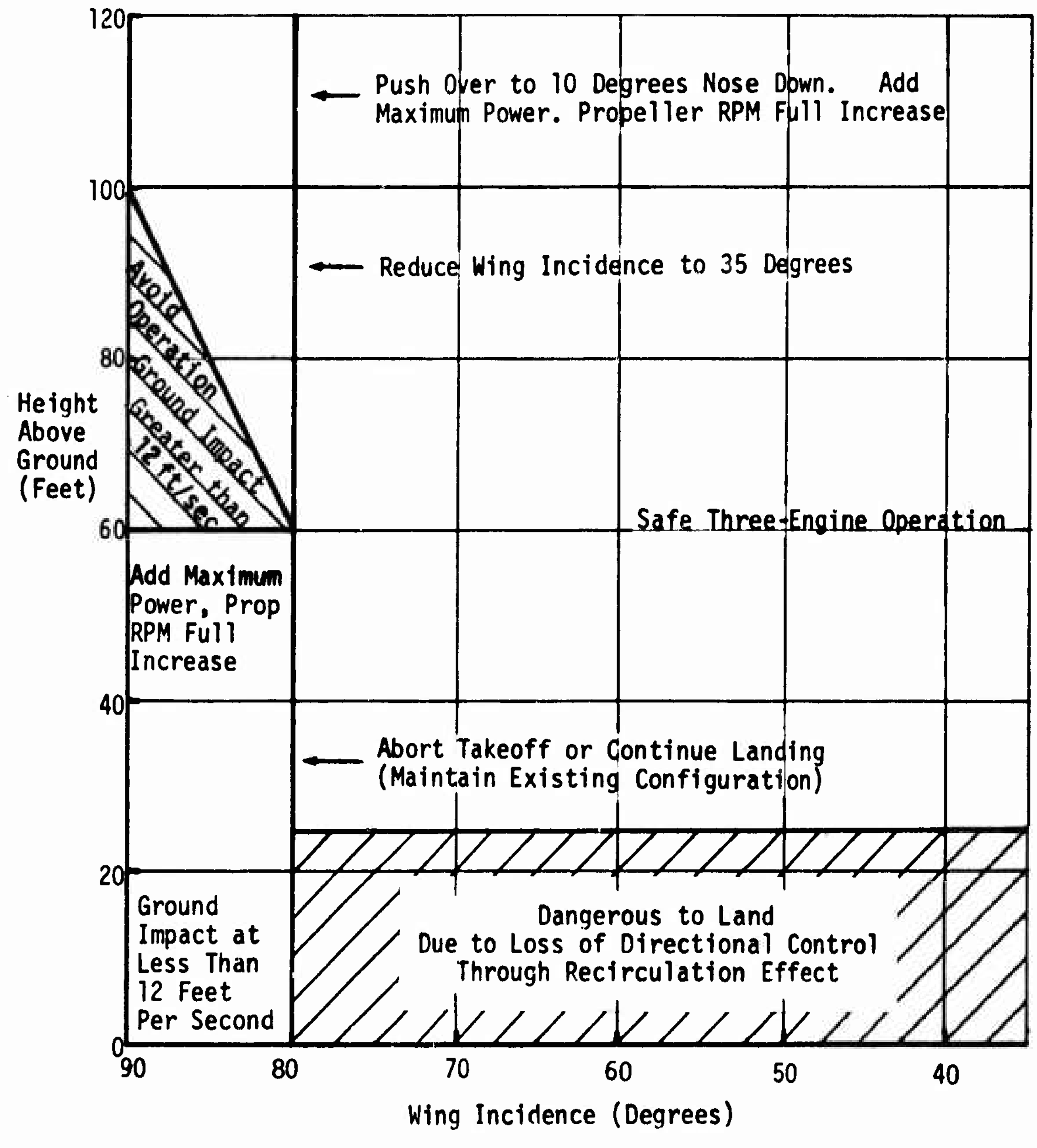


Figure 97. (U) VTOL Single Engine Failure Effects.

MODEL XC-142A
T64-GE-1 ENGINES
VERTICAL/MODULAR SYSTEM
STOL/VTOL MISSION

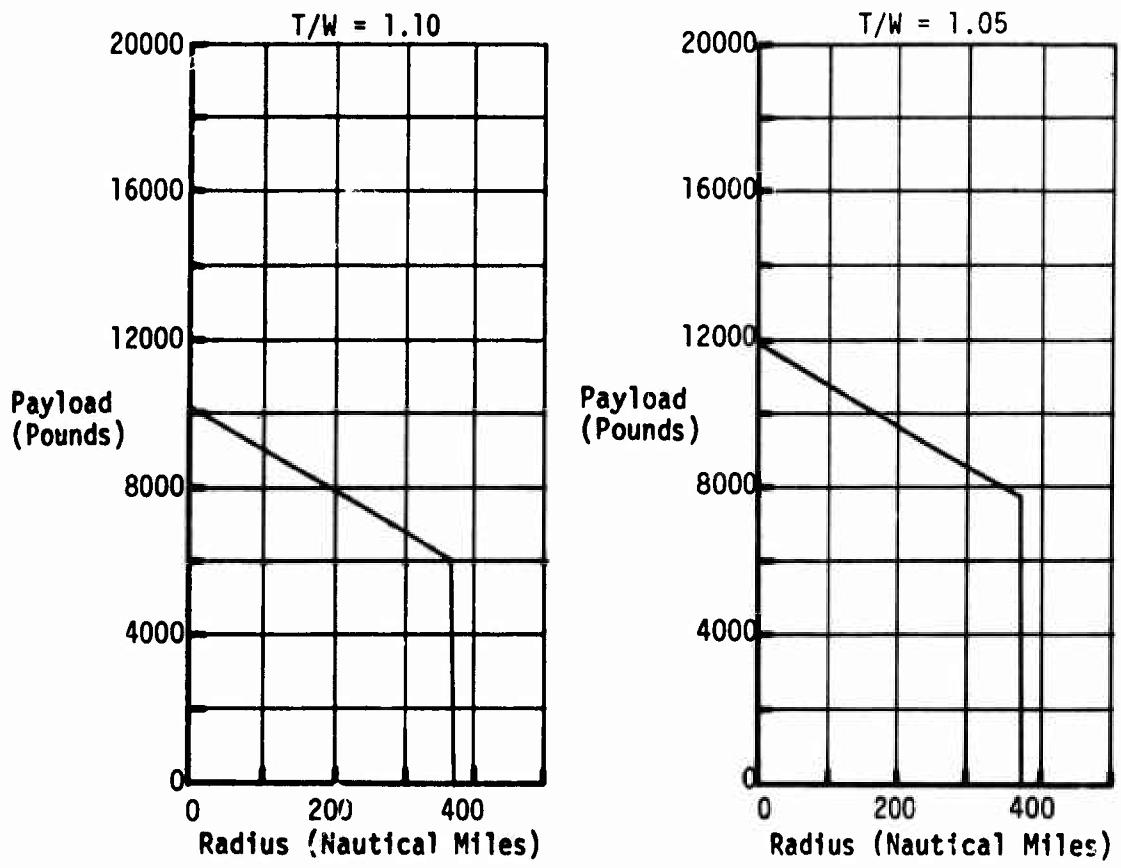


Figure 98. (U) Payload versus Radius Showing Effect of Lowering Minimum T/W from 1.10 to 1.05.

eliminated. A T/W less than 1.10 would increase the available payload because of increased maximum VTOL operational weight. Figure 98 is presented as an example of the performance gains possible, due to a change in four-engine T/W from 1.10 to 1.05. Based on these configurations, a T/W of 1.05 has been used in the evaluation of the vertical/modular cargo delivery system.

(U) OPERATIONAL COMPARISON

The conventional and vertical/modular designs have been discussed from conceptual, design, and aerodynamic points of view in the previous chapters. These chapters examined the weight penalties of 734 pounds incurred with the conventional delivery system and 1523 pounds with the vertical/modular system. This chapter compares the operational performance of the two competitive systems for:

1. Resupply of forward area combat units.
2. Deployment of forward area combat units and medical evacuation compatibility.

Based on the information contained in this chapter and on the aerodynamic performance data presented in the last chapter, the number of cycles required and/or cargo lost in performing defined wartime missions is calculated in subsequent chapters.

RESUPPLY MISSION

The resupply mission requires that the aircraft be capable of delivering cargo by four delivery modes. These delivery modes are: airdrop, hover-drop, VTOL-land and STOL-land. Each of the delivery modes is characterized by a set of peculiar problems which are best understood if discussed separately.

Airdrop Delivery Mode

This delivery mode is characterized by the requirement for a parachute to lower the cargo safely to the ground. Three phases of the operation which are of importance are cargo preparation, cargo delivery, and cargo handling time.

Cargo Preparation

Cargo preparation includes the packaging of the cargo for airdrop prior to placing the load in the aircraft and rigging the load for airdrop after the load is placed in the aircraft.

Cargo is prepared by providing a means of attaching the parachute to the load and attaching the honeycomb impact absorbing material to the load.

The rigging required to attach the parachute is similar for both the conventional and vertical/modular cargo handling systems. This rigging, for supplies on 40-inch by 48-inch wooden pallets, consists of a sling for holding the load, a disconnect device to release the descent parachute on ground impact, and the G-12 descent parachute.

The conventional delivery system, because of the loads imposed on the cargo during load exit, requires that the load be securely held together.

This is accomplished by using an A-22 container. The A-22 container provides a canvas interliner which is used to hold the load together, a sling which is used to further bind the load and to support the load from the parachute during descent, and a plywood skid which is placed under the paper honeycomb cushioning material so that the load passes smoothly over rollers on the aircraft floor during loading and airdrop.

The vertical/modular delivery system, because the load is dropped vertically and is not subjected to extraction forces, will require essentially the same rigging as above with the exception of the A-22 canvas interliner.

The preparation of 500-gallon fabric fuel drums for airdrop will be the same for both cargo handling systems. The drum is strapped on a 3/4-inch-thick plywood skid. The G-11A descent parachute is attached to the clevis fittings on each end of the drum.

The rigging required to attach the impact absorbing material to the load is the same for both the conventional delivery system and the vertical/modular delivery system. For low-velocity airdrop, less than 30 feet per second impact velocity, the impact absorbing material is paper honeycomb. For the airdrop of resupply cargo, a 6-inch thickness of honeycomb will provide adequate protection of the cargo. This material is attached to the bottom of the load, and held in place by a 1/2-inch-thick plywood skid (see Figure 99) strapped to the load with metal banding. No honeycomb is required for the safe delivery of 500-gallon fabric fuel drums. (As noted in Reference 55, a full fuel drum is tested by a 12-foot free-fall drop which will subject the drum to approximately the same impact velocity as during airdrop.)

The rigging in the aircraft for the conventional cargo handling system consists of an array of straps and strap cutters, and a load extraction system. The straps are used to restrain the load for flight conditions up to the point of load release. At the time of load release, the extraction system, consisting of a 15-foot-diameter parachute, is deployed and pulls the extraction line taut and exerts a pull on the restraint strap cutters, which cut the load restraint straps. The load is then free to roll out of the aircraft under the force of gravity. The aircraft must fly in a tail-down attitude to allow the load to exit. As the load clears the aircraft, a static line attached to the aircraft and to the descent parachute bag deploys the descent parachute.

The rigging in the aircraft for the vertical/modular cargo handling system consists of a fitting located on the aircraft structure over each pallet position. To this fitting is tied a nylon static line used to deploy the main descent parachute when the load is released. The vertical/modular system, therefore, eliminates most of the rigging inside the aircraft. Table XXX is a summary of the airdrop rigging weight.

Cargo Delivery

The delivery of cargo by airdrop varies between the two delivery systems. A functional comparison will illustrate the major differences, and a quantitative comparison will illustrate the impact of these differences.

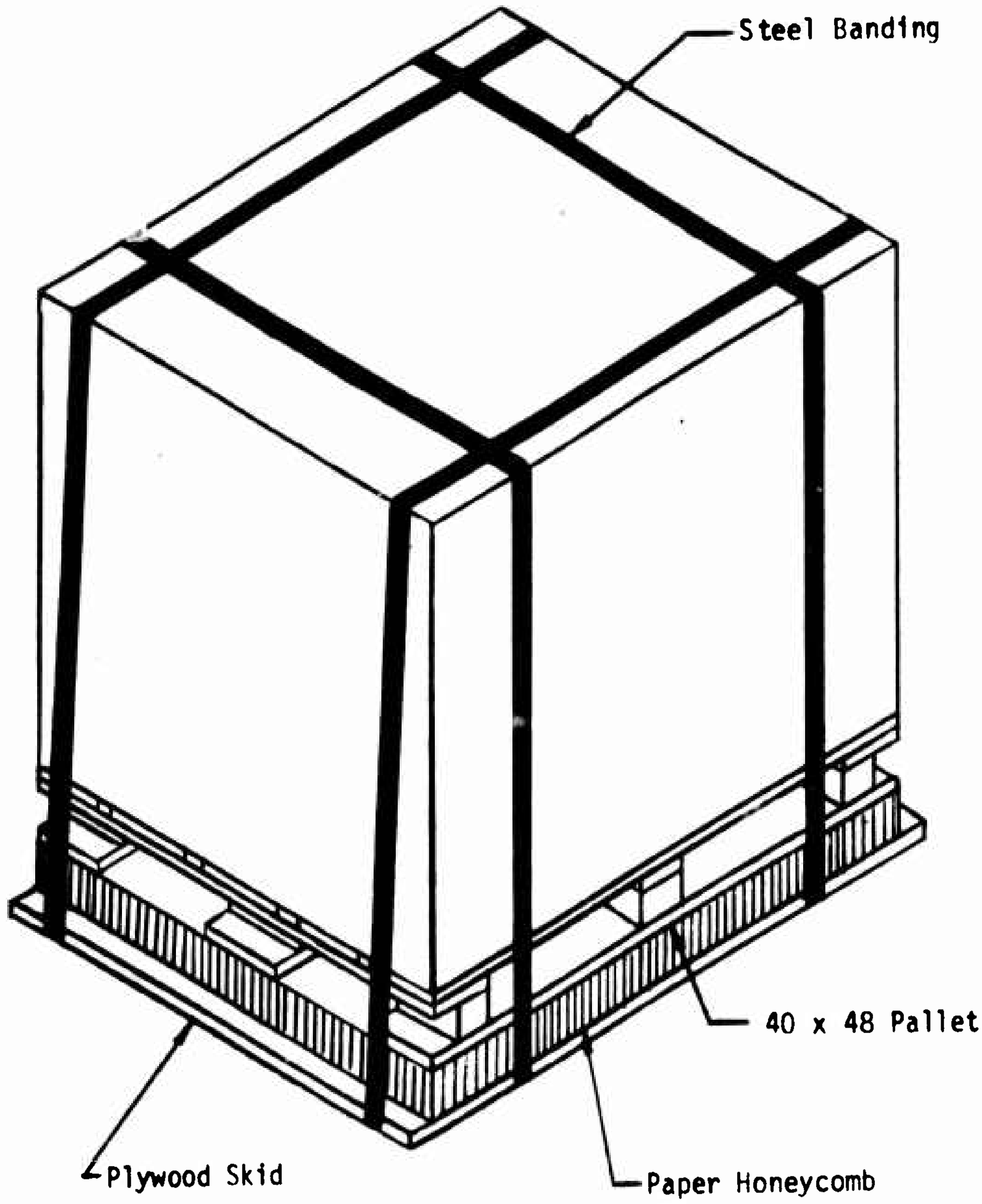


Figure 99. (U) Attachment of Honeycomb to Cargo Module.

TABLE XXX (U)
AIRDROP RIGGING WEIGHT COMPARISON

ITEM	500-Gal. Fuel Drums		40- x 48-Inch Pallets	
	Conv. (lb)	V/M (lb)	Conv. (lb)	V/M (lb)
A-22 Container Inner Liner	-	-	42	-
A-22 Container Sling	-	-	25	25
A-22 Container Risers	-	-	4	4
A-22 Container 1/2" Plywood Skid	-	-	23	23
Honeycomb Cushioning	-	-	13	13
40-Inch x 48-Inch Wooden Pallet	-	-	100	100
3/4" Plywood Skid	60	60	-	-
Restraint Straps	20	20	-	-
Main Descent Parachute	250	250	120	120
Extraction Parachute*	14	-	14	-
Load Release Gate*	15	-	15	-
Extraction Lines*	10	-	10	-
Misc. Rigging	5	5	5	5
Total Airdrop Rigging Wt./Pallet	345**	335	338**	290

* These items are used only once in each aircraft load.
** This total includes an average weight for the items marked thus * based on three fuel drums and six or seven 40-inch x 48-inch pallet loads.

The functions which are required to deliver cargo by airdrop with the conventional cargo handling system are shown in Figure 100. Figure 101 shows the functions required to deliver cargo by airdrop with the vertical/modular cargo handling system. The vertical/modular cargo handling system eliminates the extraction parachute and the associated functions from the delivery sequence. As has been discussed, the rigging for the vertical/modular system is much simpler due to the elimination of the extraction parachute.

Two items, cargo damage and delivery accuracy, must be considered to make a quantitative comparison of the actual cargo delivery as performed by the two delivery methods.

Cargo damage is the sum of two quantities: damage to the cargo suffered on impact, and destruction of the cargo because of a failure in the main descent parachute system. There should be no damage to cargo when the load impacts in a normal manner because the packaging and cushioning of loads are designed to prevent damage. However, there are several abnormal ways in which a load can impact. Some of these are: side drift of the

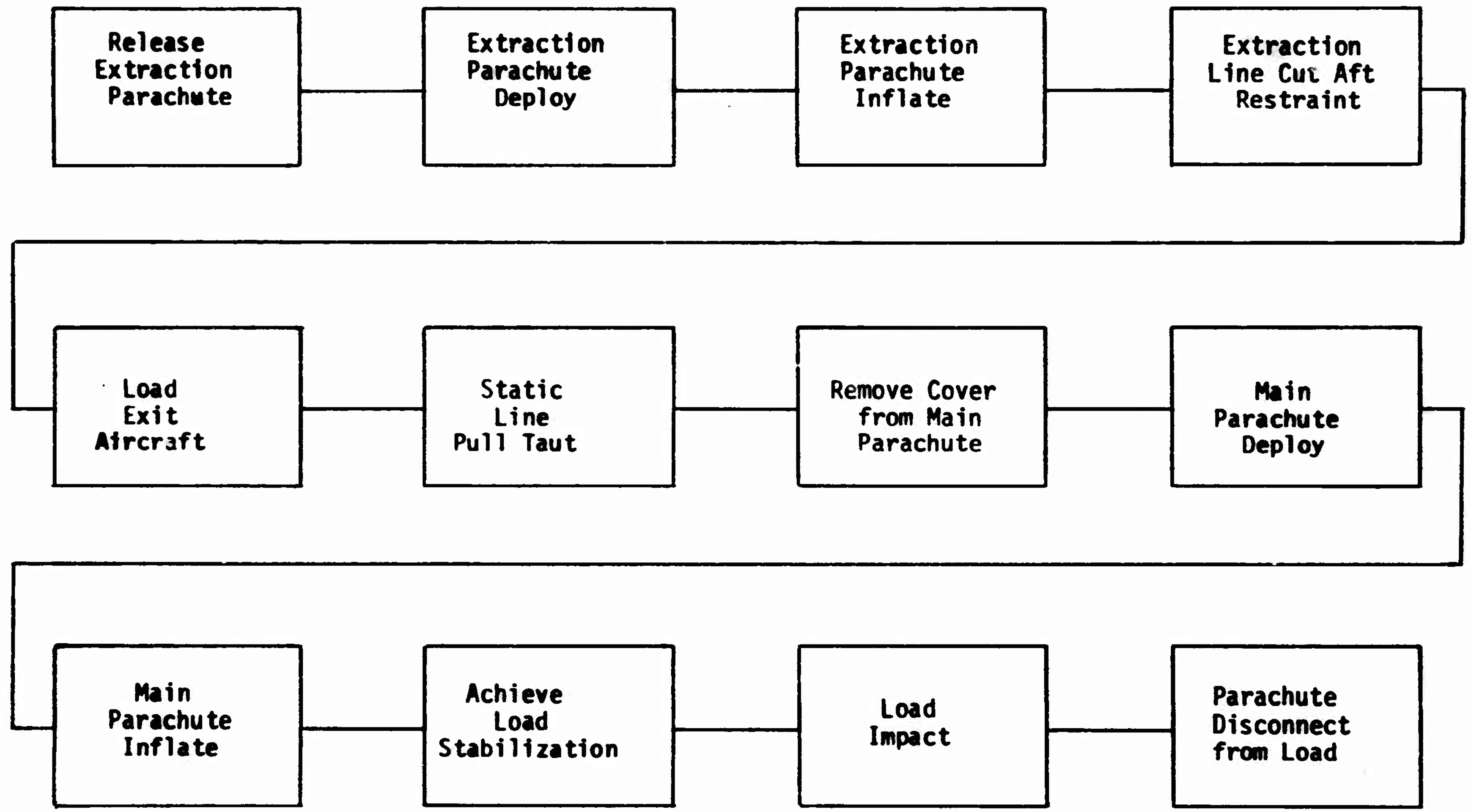


Figure 100. (U) Airdrop Delivery Sequence – Conventional Cargo Handling System.

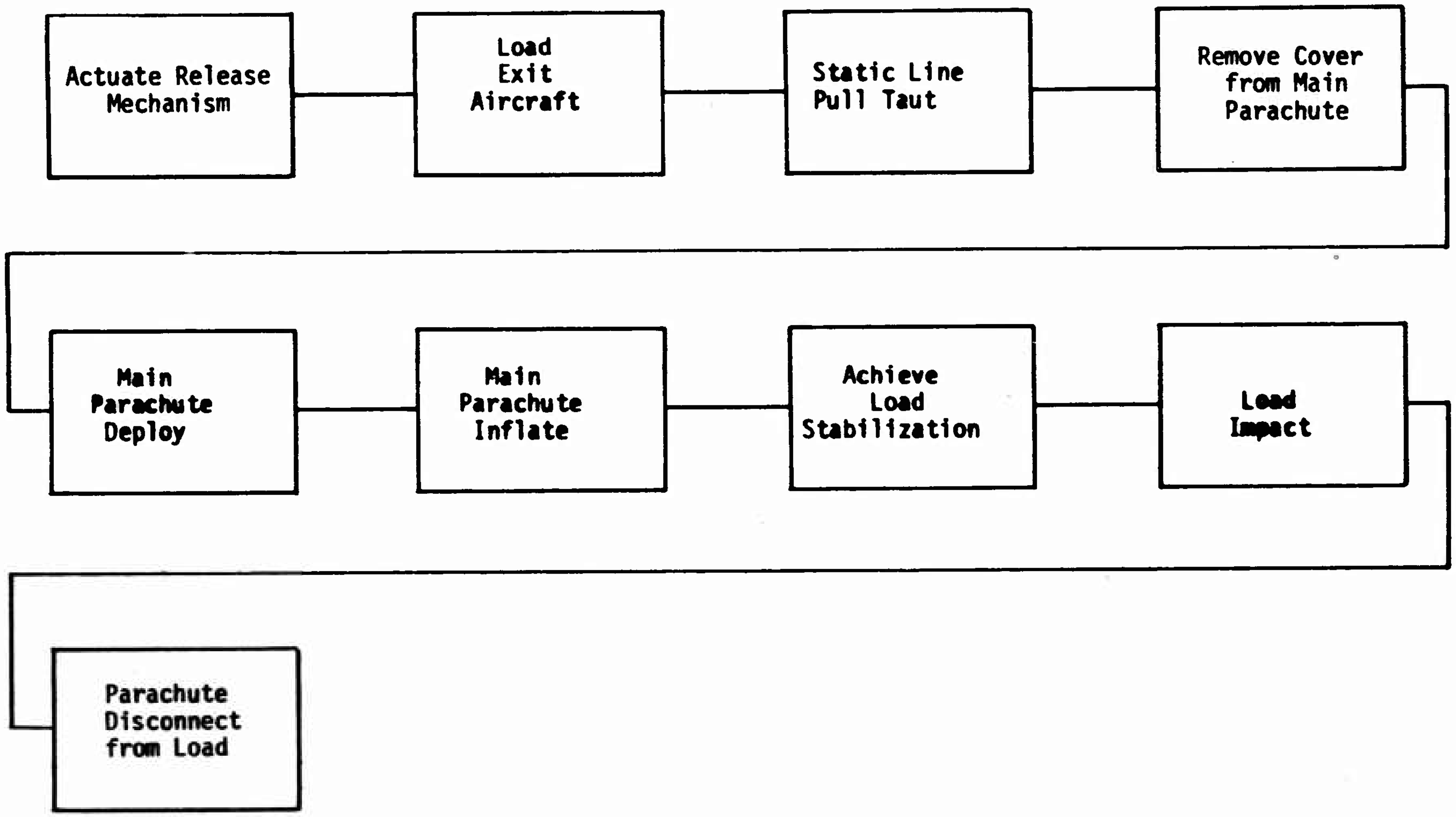


Figure 101. (U) Airdrop Delivery Sequence – Vertical/Modular Cargo Handling System.

load caused by the prevailing wind, oscillation of the load causing a horizontal velocity on impact, impact of the load on uneven ground, or dragging of a load because of the failure of the parachute disconnect to function properly. All of the items will cause damage to the cargo because of uneven crushing of the cushioning material or tumble of the load (see Figure 102). It is to be expected that one of these abnormal landing conditions will occur in many of the loads dropped. Even when an abnormal landing does occur, only a portion of the cargo will be unusable. It has been assumed for this evaluation that 2 percent of the airdrop cargo will be lost due to impact damage.

In addition to the cargo lost due to impact damage, there will be cargo lost due to a failure of the parachute descent system. An analysis of data contained in References 66 and 79 indicates the frequency of this type of failure. Reference 66 states that for 360 A-22 container drops, there were 9 malfunctions which caused the load to be destroyed. This is a failure rate of 2.5 percent. Reference 79 which recorded three malfunctions out of a total of 65 drops suffered a failure rate of 5 percent. A failure rate of 3 percent has been used in this evaluation.

These two loss figures of 2 percent and 3 percent are assumed to be the same for both cargo handling systems.

There are many variables which affect the accuracy with which a cargo load can be airdropped on a given target. The variables which will cause a load to be off target are: aircraft position error, wind velocity estimation error, main parachute opening time variation, variation in the rate of fall, and aircraft altitude error. Each of these factors will combine to reduce the probability that the load will land within a selected drop zone. It is academic to observe that the larger the drop zone, the more likely it is that the load will land within the desired area. Present procedures for determining the calculated aerial release point (CARP) for a cargo load prescribe that the above factors will be considered in calculations based on some expected value for each. In reality, this expected value is not an exact number, but there is some distribution of actual values around the expected value. An example of this distribution was shown by USAF Project "Close Look" (Reference 104, Appendix 10 to Annex A, Figures 3 through 10). The actual values of the variables in any single drop may all be additive, causing a large error; or some may in effect cancel each other, causing a small error. Airdrop field experience was available in the form of the results of the 1964 Military Airlift Command aerial delivery competition. The accuracy data from the competition was assumed a reasonable, and probably conservative, estimate of the inaccuracy resulting from the above factors. This competition pitted two of the best aerial delivery crews from each of eleven MAC wings. In all, 22 crews participated in the competition; 10 crews flew C-130 aircraft and 12 crews flew C-124 aircraft. From the data contained in these results (Reference 79), it is possible to construct a curve of the percent of loads expected to fall into a given target area. This is shown in Figure 103 for both C-130 and C-124 aircraft. Examination of the plot shows that the C-124 crews were more accurate in their drops. The C-124, which drops cargo out the bottom, does not require the pendulum release mechanism, the extraction parachute, or the restraint strap cutters required by the C-130. As each of these items

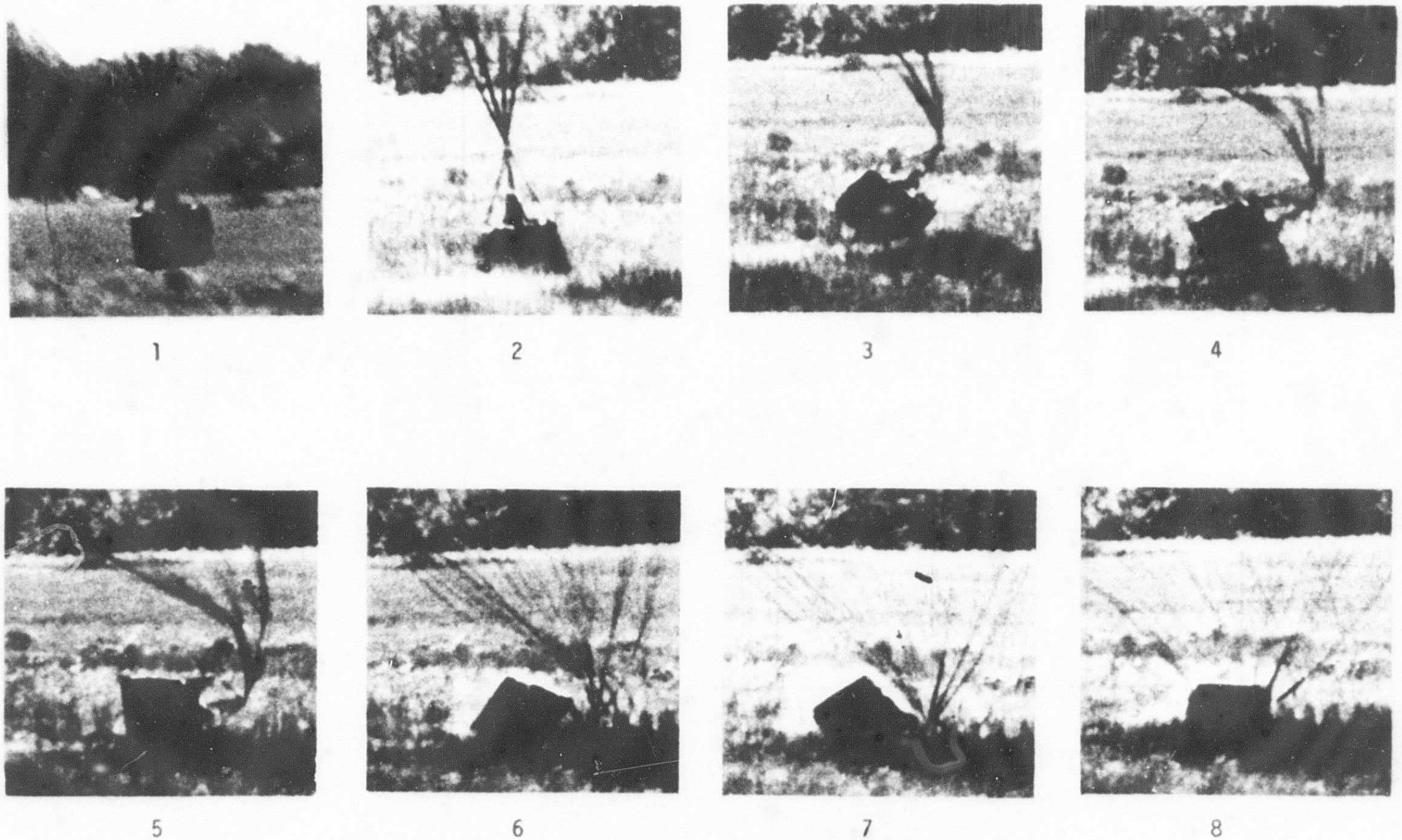


Figure 102. (U) Impact and Tumble of an A-22 Airdrop Module.

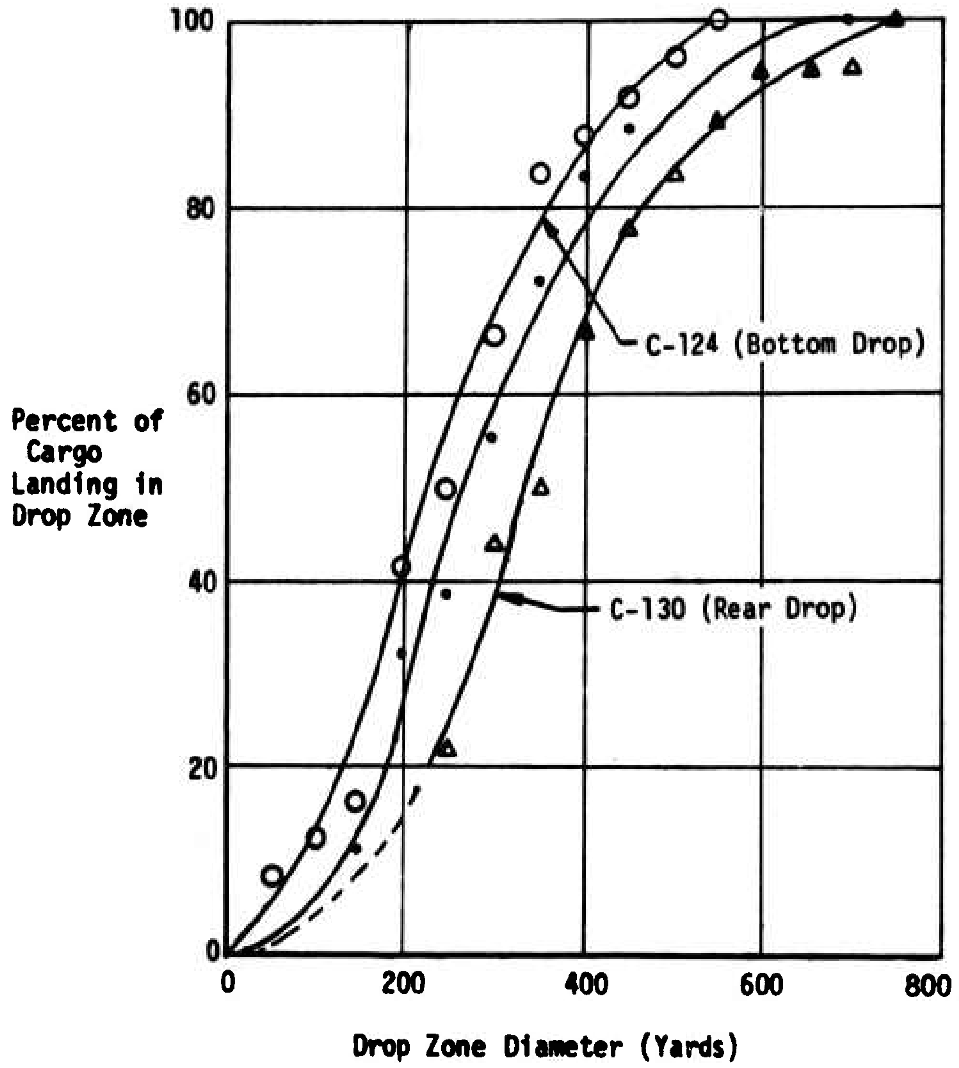


Figure 103. (U) Accuracy Comparison of C-124 and C-130 1964 MAC Airdrop Competition.

affects the load exit time, the C-124, because it eliminates these variables, would be expected to be more accurate than the C-130, with the greatest improvement expected in the longitudinal direction.

Since dropping out the bottom of an aircraft is expected to decrease the longitudinal error, the MAC competition results were examined to determine the magnitude of the improvement in longitudinal accuracy. Figure 104 shows the variation of both longitudinal and lateral accuracy of the C-124 and the C-130. Examination of the plots shows that the C-124 crews' longitudinal accuracy was only slightly better than the C-130 crews' and that the C-124 lateral accuracy was much better. An extensive examination of the airdrop systems and procedures used by the two aircraft failed to reveal any differences which would account for the lateral error difference. Because of this, the airdrop accuracy comparison of the conventional and vertical/modular systems was based on the accuracy achieved by the C-124 as shown in Figure 103.

The MAC competition was conducted by dropping a single load from each aircraft. Under actual combat conditions, an aircraft could drop a full payload of cargo modules. If all cargo modules do not exit from the aircraft at the same time, they will be spaced along the flight path and this will have an adverse effect on the overall drop accuracy. The effect of multiple loads on accuracy is nearly the same with the two systems, conventional and vertical/modular.

The conventional delivery system has a separation between loads by virtue of the delivery procedure. Figure 105 traces the time history of seven modules released simultaneously at 120 knots. The elapsed time between modules crossing the aft ramp results in 160-190 yards separation between the first and last modules. This can be reduced by making multiple passes over the drop zone, but this, in turn, requires that payload be reduced because of center-of-gravity limits of the aircraft. Figure 106 shows the effect of dropping the full cargo load in one, two, or three passes, dropping an equal number of cargo modules each pass on the multiple pass drops. Using the two-pass case for an example, if six cargo modules were on board the aircraft, three would be dropped on each pass. The three cargo modules remaining would shift the aircraft c.g. ahead of the forward limit, and the aircraft could not be trimmed to the proper flight attitude (see "Stability and Control" chapter). Thus, if two passes are anticipated, the maximum number of cargo modules on board could be only four. This would result in a penalty in aircraft productivity. Because of this, the full payload of cargo modules is assumed to be dropped in one pass in this evaluation. As discussed in the "Stability and Control" chapter, the response of the aircraft in this case is within the aircraft limits.

For the vertical/modular system, all loads can theoretically be dropped at one time. This would likely cause entanglement of parachutes and riser lines. Because of this, a spacing of 25 yards between loads has been assumed for the vertical/modular system. Using the data above and the single load accuracy of the C-124 aircraft, the probability of a load landing within a given drop zone diameter was determined. Figure 107 shows the results of this analysis for a single load, four loads and the maximum

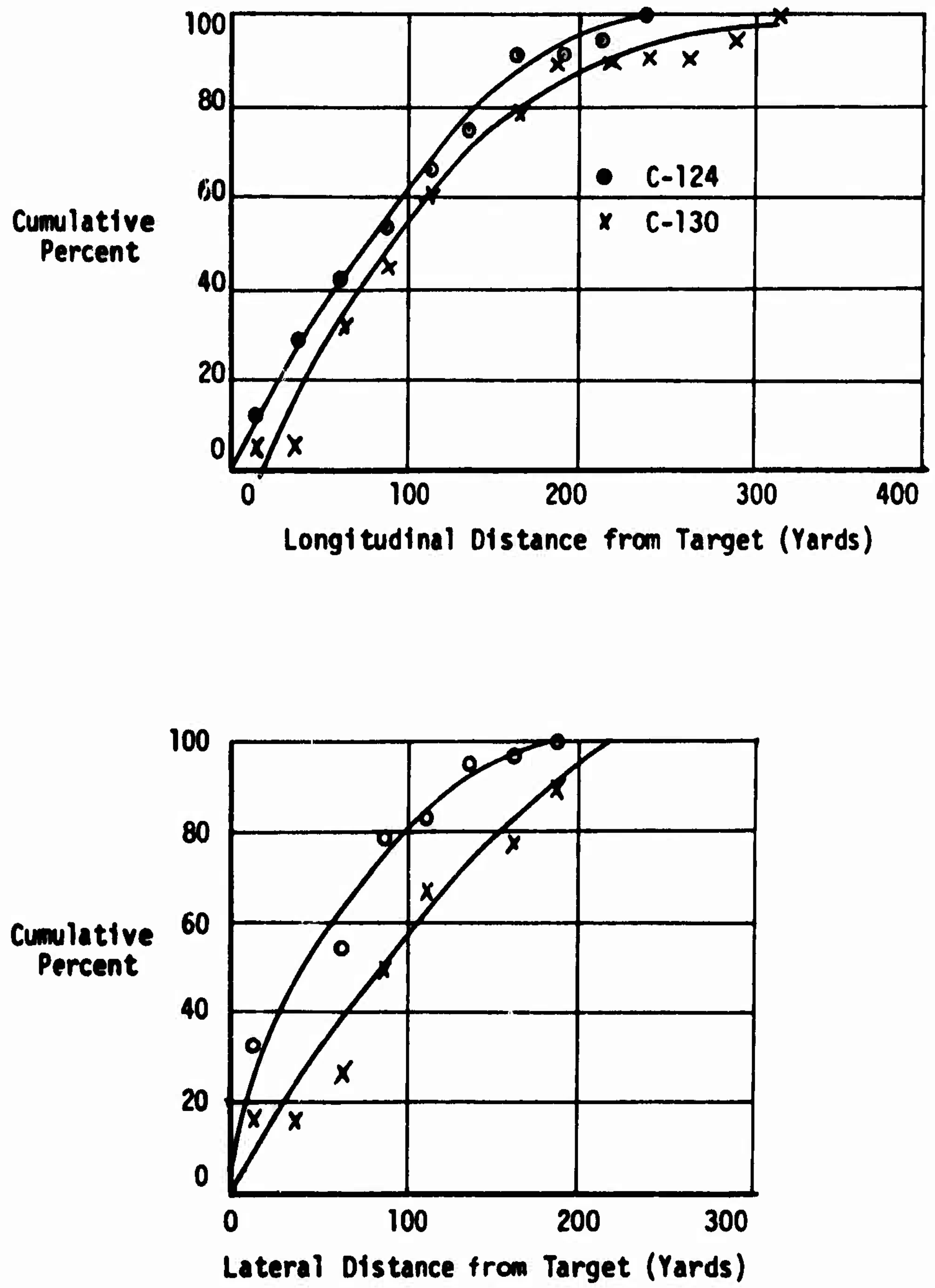


Figure 104. (U) Comparison of Longitudinal and Lateral Error for C-124 and C-130 Aircraft, MAC Aerial Delivery Competition 1964.

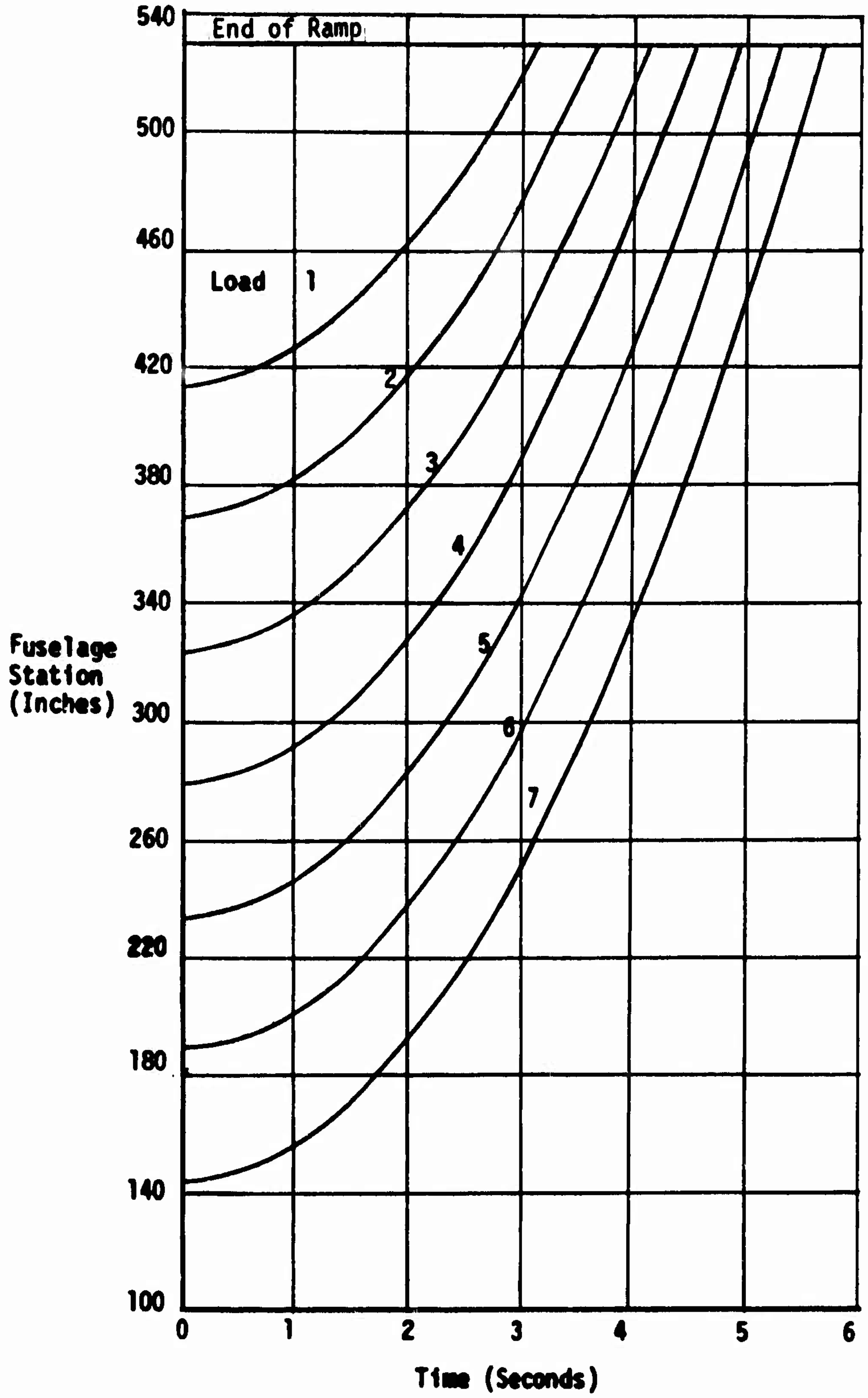


Figure 105. (U) Cargo Load Location as a Function of Elapsed Time After Load Release – Conventional Delivery System.

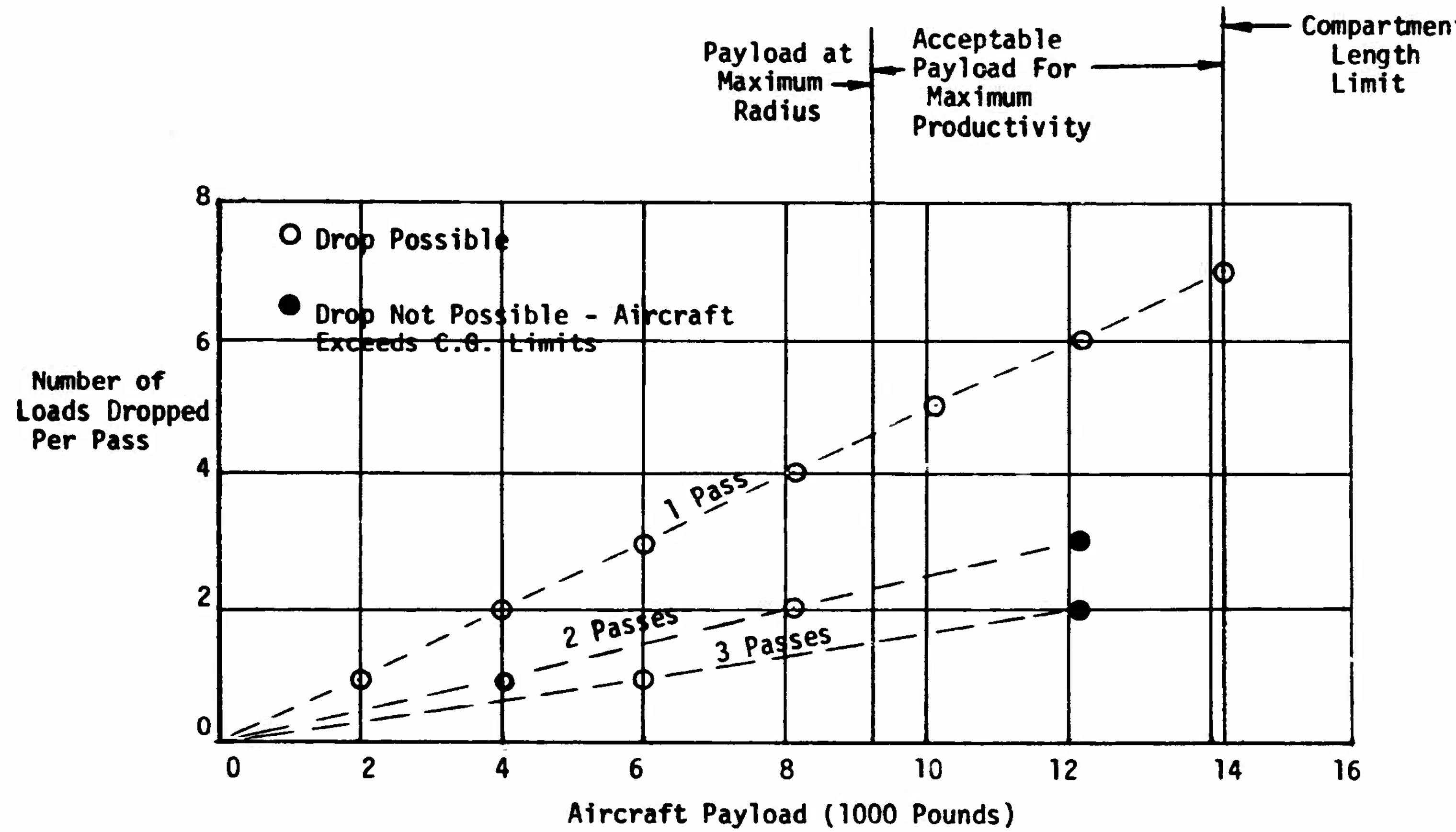


Figure 106. (U) Number of Pallets Droppable per Pass for Aircraft with Conventional System to Remain within C.G. Limits.

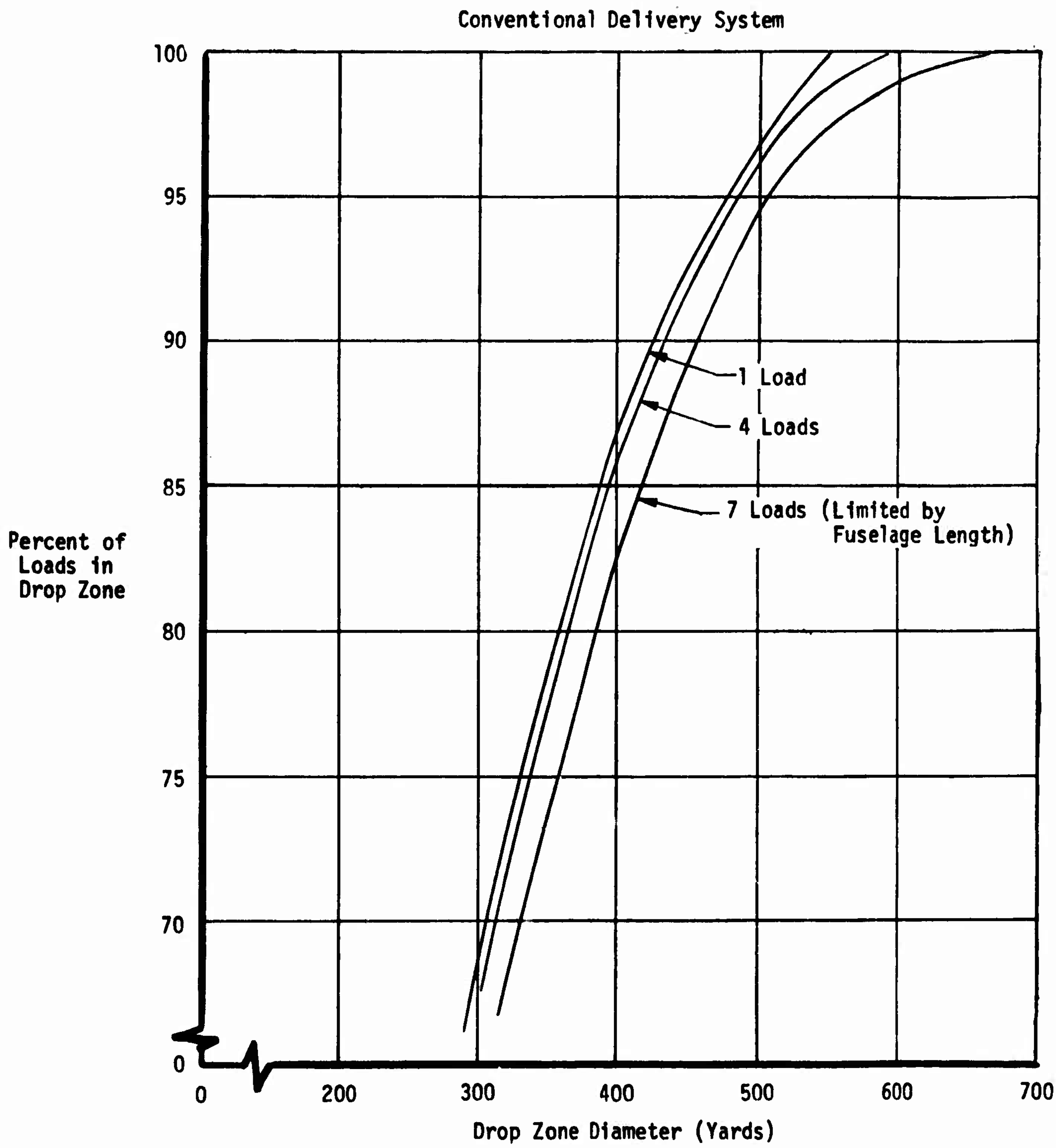
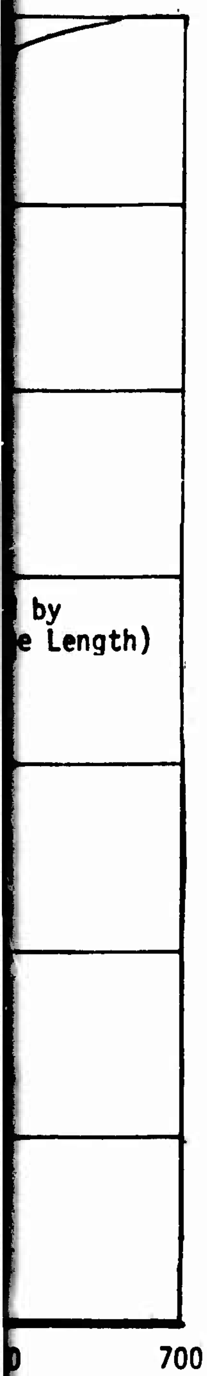
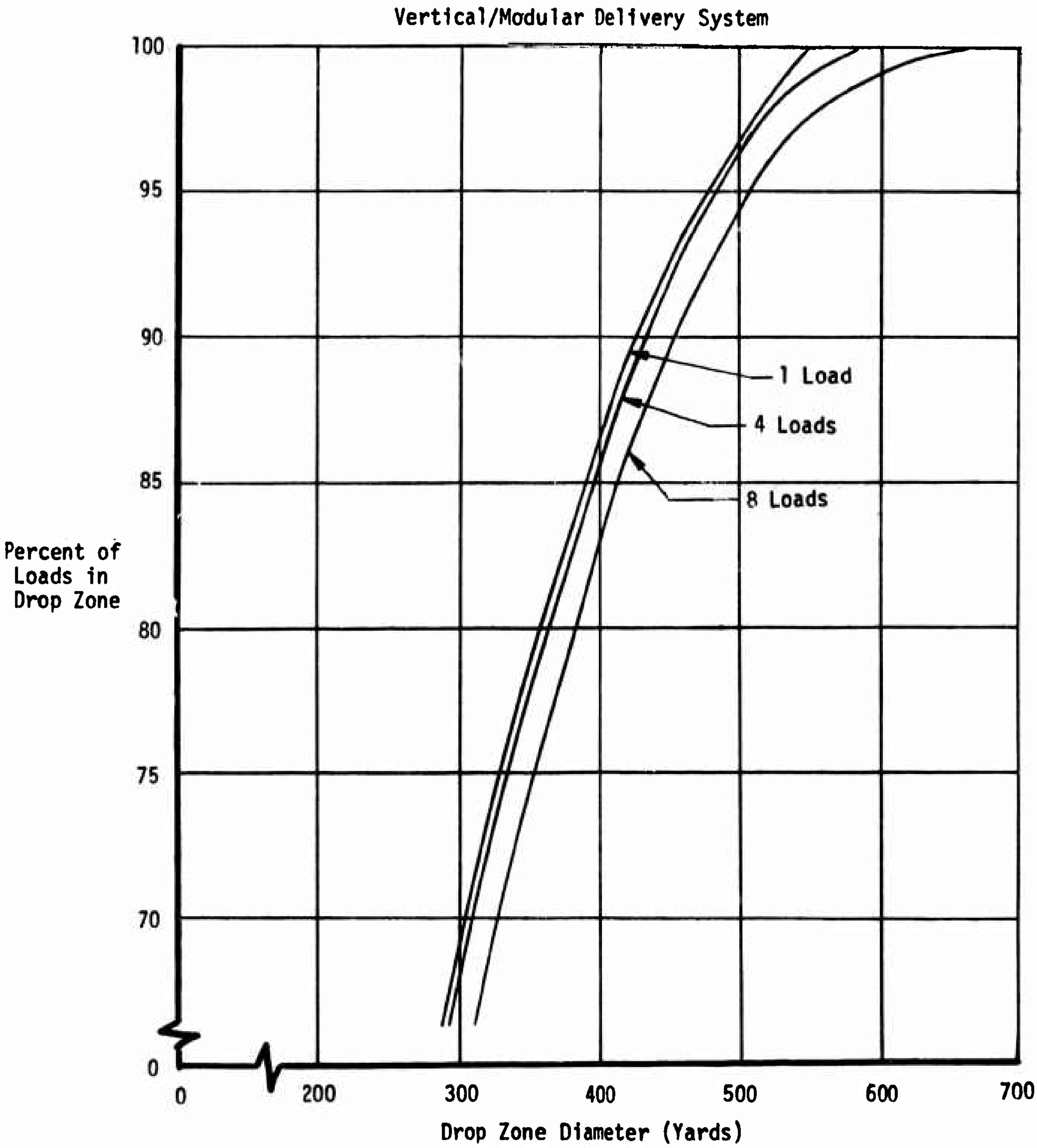


Figure 107. (U) Delivery System Accuracy as a Function of Drop Zone Diameter for Single & Multiple Loads in a Single Pass.


by
e Length)
700


Vertical/Modular Delivery System
100
95
90
85
80
75
70
0
Percent of Loads in Drop Zone
1 Load
4 Loads
8 Loads
0
200
300
400
500
600
700
Drop Zone Diameter (Yards)

2

number of loads which can be accommodated by each system. To aid in the calculations, the damage and accuracy loss information was combined and is shown in Figure 108 as a function of mission radius (longer range has lower payload, therefore fewer modules in sequence) and drop zone diameter. Since the complete analysis is based on the delivery of a fixed cargo quantity, that cargo lost must be replaced. Figure 109 and Table XXXI show the quantity of cargo which must be dispatched to assure that one ton of usable cargo lands within a given drop zone diameter as a function of mission radius.

Cargo Handling Time

The ground time to load the aircraft with each cargo handling system was determined from time line analysis of the complete procedure. Cargo loading time was determined for the maximum number of airdrop loads which could be carried with each cargo handling system. Cargo unloading time was not determined, as this occurs when the aircraft is airborne. The rigging required to prepare for the delivery of supplies by airdrop has been described previously. Analysis of the rigging procedure shows that a trained crew can load a full complement of airdrop loads into an aircraft equipped with the conventional cargo handling system in approximately 18 minutes. The time to load a full complement of airdrop loads into an aircraft equipped with the vertical/modular cargo handling system is approximately 8 minutes. This time will, of course, vary with the quantity of cargo loaded. However, in the mission radius range applicable to the airdrop mission, the difference in payload is small and a constant time was used in the calculations.

Hover-Drop Delivery Mode

As the name implies, this delivery mode occurs when the aircraft is hovering. Additionally, by definition, the aircraft is within 15 feet of the ground during load release. When hovering within 15 feet of the ground, the impact velocity of a free-falling cargo module will be approximately the same as the impact velocity of cargo modules dropped by parachute. This delivery mode requires that the aircraft approach the drop zone as if to make a vertical landing. At a point between 5 and 15 feet above the ground, the aircraft will hover and discharge the cargo.

Cargo Preparation and Delivery

The conventional cargo delivery system uses a dump truck delivery technique. This requires that the aircraft be positioned in a slight tail-down attitude at the hover-drop altitude. The rear doors are then opened and the load(s) released and allowed to roll out of the aircraft and fall to the ground. Figure 110 shows the XC-142 dropping cargo in this manner. Rigging for this delivery technique will be almost the same as for airdrop, except that the extraction parachute, main descent parachute, and the load sling are not required. A load release gate is required and a method of actuating it must be provided, as the extraction parachute is not used. Although detail design of a restraint release method was not conducted, a simple arrangement requiring that one pin be pulled to release the load

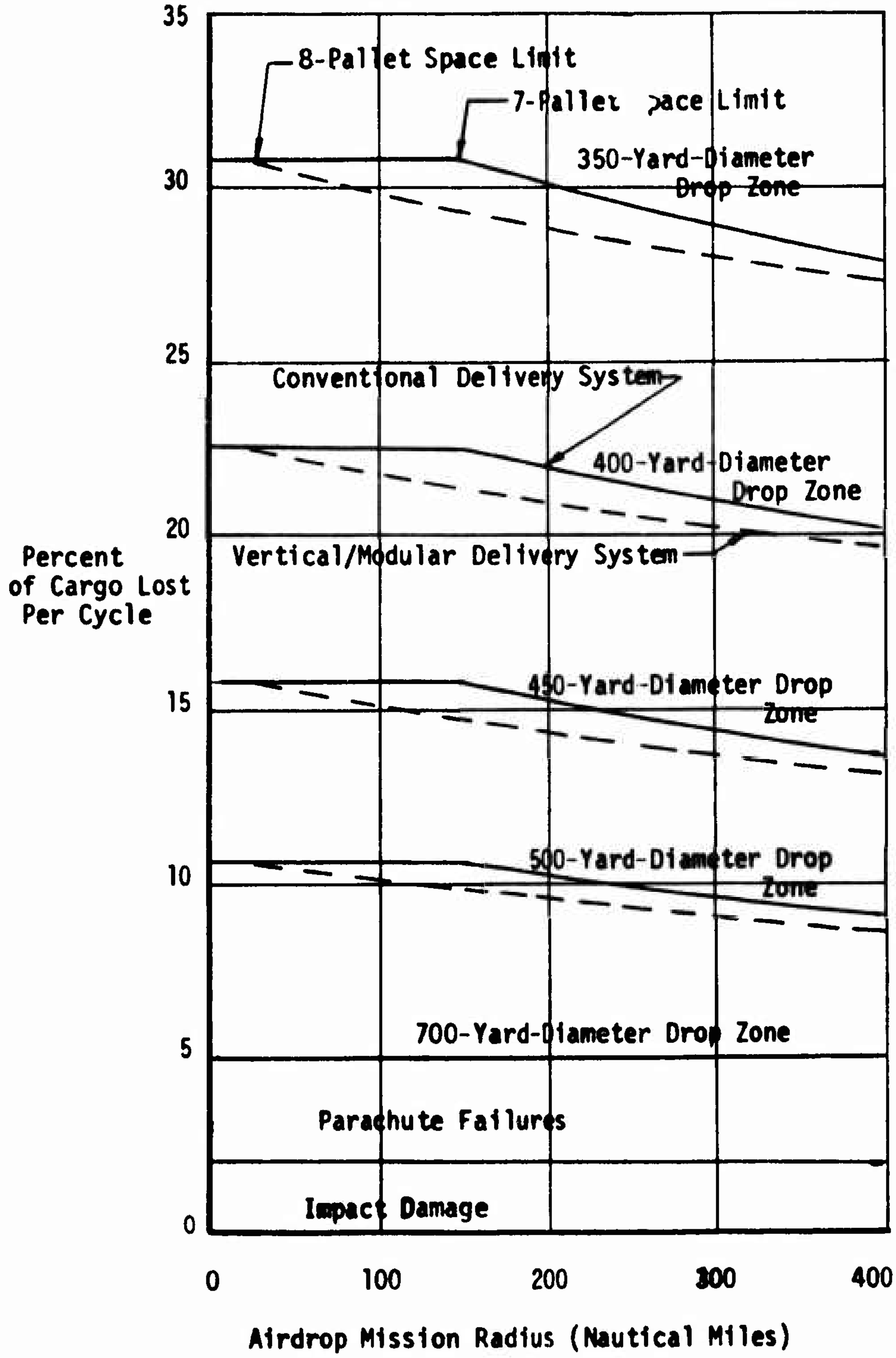


Figure 108. (U) Cargo Lost and Damaged Versus Radius for Variations in Drop Zone Diameter.

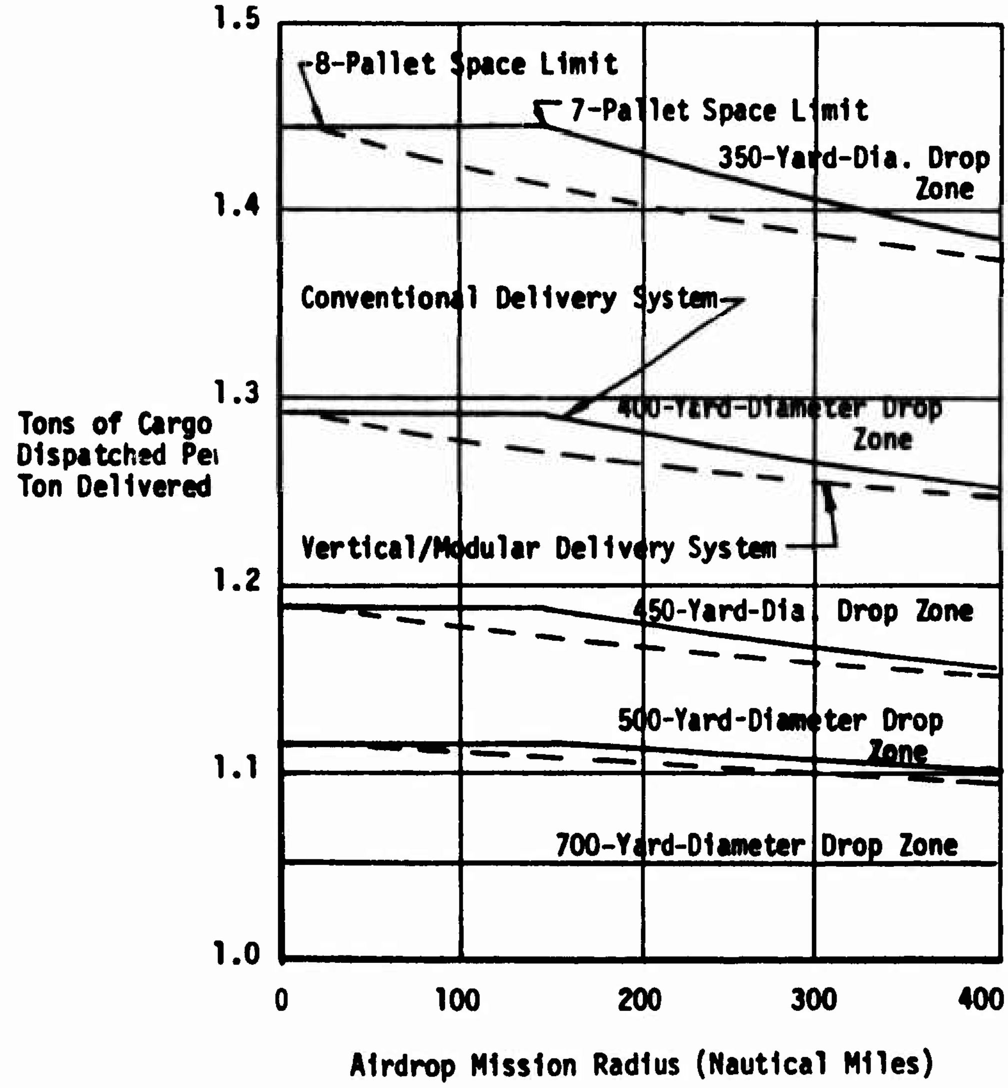


Figure 109. (U) Tons of Cargo Which Must be Dispatched to Deliver One Ton of Cargo Within the Drop Zone by Airdrop versus Mission Radius.

TABLE XXXI (U)
TONS OF CARGO DISPATCHED TO AIRDROP ONE TON
OF USABLE CARGO WITHIN THE DROP ZONE

DELIVERY SYSTEM	DROP ZONE DIAM. - YARDS	AIRDROP MISSION RADIUS — NAUTICAL MILES						
		23	100	148	200	248	300	400
Vertical/Modular	350	1.444	1.425	-	1.404	-	1.389	1.375
	400	1.290	1.278	-	1.266	-	1.254	1.245
	450	1.188	1.179	-	1.168	-	1.158	1.151
	500	1.117	1.113	-	1.106	-	1.100	1.093
	700	1.052	1.052	1.052	1.052	1.052	1.052	1.052
Conventional	350	1.446	1.446	1.446	1.431	1.418	1.406	1.385
	400	1.290	1.290	1.290	1.281	1.274	1.266	1.252
	450	1.188	1.188	1.188	1.180	1.174	1.168	1.155
	500	1.119	1.119	1.119	1.114	1.110	1.106	1.100
	700	1.052	1.052	1.052	1.052	1.052	1.052	1.052

Figure 110. (U) Dump Truck Hover-Drop From XC-142A.

seems feasible. The aircraft must have a slow forward velocity when multiple loads are being dropped, or the loads must be dropped individually and the aircraft moved after each load, to prevent contact between loads.

The vertical/modular cargo delivery system will drop cargo from hover the same as from airdrop. The parachute, and all rigging required to attach it, is not used for hover-drop. Cushioning material will be the same as for airdrop. A comparison of the hover-drop rigging weight for both systems is shown in Table XXXII.

TABLE XXXII (U)
HOVER DROP RIGGING WEIGHT COMPARISON

ITEM	500-Gal. Fuel Drums		40- x 48-Inch Pallets	
	Conv. (lb)	V/M (lb)	Conv. (lb)	V/M (lb)
A-22 Container Inner Liner	-	-	42	-
A-22 Container 1/2" Plywood Skid	-	-	23	23
Honeycomb Cushioning	-	-	13	13
40-Inch x 48-Inch Wooden Pallet	-	-	100	100
3/4" Plywood Skid	60	60	-	-
Restraint Straps	20	20	-	-
Load Release Gate*	15	-	15	-
Misc. Rigging	5	5	5	5
Total Hover Drop Rigging Wt.	90**	85	186**	141

* These items are used only once in each aircraft load.
** This total includes an average weight for the items marked thus *.

Cargo Damage Due to Impact

Cargo damage caused by impact was assumed the same for hover-drop as for airdrop for the conventional cargo handling system. This is because in hover-dropping out the back of the aircraft with the conventional cargo handling system, every load will tip off the aft ramp (see Figure 110) and strike the ground on an edge, subjecting the cargo on that edge of the pallet to higher than normal impact loads. This is conservatively assumed to result in 2 percent of the cargo being damaged.

With the vertical/modular cargo handling system, loads will impact flat on a selected terrain and should not suffer measurable damage.

Cargo Handling Time

Time line analysis of the loading and rigging procedure for a full complement of hover drop loads in an aircraft equipped with the conventional cargo handling system will require approximately 12 minutes. The loading and rigging of an aircraft equipped with the vertical/modular cargo handling system will require approximately 5 minutes; however, the time used in calculations will be 8 minutes to allow for refueling time.

Air-land Delivery Mode

The aircraft used in this evaluation has the capability to operate STOL or VTOL. The basic difference between these flight modes is payload capacity, which is discussed in the Aerodynamics Performance Comparison chapter. Operationally this difference in payload capacity will cause a difference in cargo loading and unloading time. Based on the available payload at typical mission radii for the two delivery modes and the actual loading procedures for the two cargo handling systems, the cargo handling times shown in Table XXXIII were determined by time line analysis.

Rigging required for the air-land mission consists of tiedown straps to restrain the cargo. The conventional cargo handling system utilizes the tiedown straps to restrain cargo to the required load factors. The vertical/modular cargo handling system utilizes tiedown straps to restrain cargo for the vertical load factor. Restraint in forward, aft, and lateral directions is provided by plug-in restraint fittings. All cargo except fuel is assumed to be palletized on 40-inch by 48-inch wooden pallets.

DEPLOYMENT MISSION

The aircraft, when equipped with a cargo handling system, must retain its capability to transport military vehicles, combat troops and litter patients. Both cargo handling systems in this evaluation satisfy this requirement. The efficiency with which the two cargo handling systems meet this requirement will vary. An investigation was made to quantify this variation.

A combat brigade of an airmobile division was used to make this comparison. To assess the sensitivity to variations in cargo, three individual combat units and the brigade base units were assumed to be transported separately. These combat units were: infantry battalion, engineering platoon, and 105mm howitzer battery. The number of men and type and number of vehicles from each of these units are shown in Tables XXXIV and XXXVII.

Utilizing a 1/100 scale drawing, the number of loads required to transport each of the above units as a function of aircraft payload was determined. This information is shown in Figure 111. The curves can be best explained by considering two limiting cases. First, the volume of the aircraft is fixed, and at some point the aircraft will be volume-limited but not necessarily payload-limited. This results in the curves being flat to the right of the X in Figure 111. The second consideration is the point where the payload of the aircraft is utilized before the total volume is filled. This is

TABLE XXXIII (U)
TOTAL GROUND TIME (IN MINUTES)

Mission	Cargo	Nominal Loading Time Conv	Nominal Loading Time Vert/Mod	Nominal Unloading Time Conv	Nominal Unloading Time Vert/Mod	Calculation Values Total Ground Time Conv	Calculation Values Total Ground Time Vert/Mod
Resupply							
STOL-land	Pallets or 500-Gallon Fuel Drums	9	8	6	5	15	13
VTOL-land		6	6	4	4	10	10
Airdrop		18	8	-	-	18	8
Hover-drop		12	5	-	-	12	8*
Deployment							
Brigade Base Units	169 Vehicles 1070 Troops	8 3*	8 3*	2 2	2 2	10	10
Infantry Battalion	34 Vehicles 767 Troops	8 3*	8 3*	2 2	2 2	10*	10*
Engineering Platoon	25 Vehicles 35 Troops	9 3*	9 3*	3 2	3 2	12	12
Howitzer Battery	9 Vehicles 89 Troops	7* 3*	7* 3*	2 2	2 2	10*	10*

*Assumed limited by 8-minute average refueling time.

TABLE XXXIV (U)
UNIT COMPOSITION – INFANTRY BATTALION TOE 7-55 T

LINE ITEM NUMBER	EQUIPMENT DESCRIPTION	QUANTITY
460080	3/4-Ton Truck W/Winch	2
461206	1/2-Ton Truck, Platform	19
461790	1/4-Ton Truck, Jeep	5
461793	1/4-Ton Truck, Jeep (for 106mm)	8
	Troops	767

TABLE XXXV (U)
UNIT COMPOSITION – ENGINEERING PLATOON
(Hq + 3 SQUADS) PART OF TOE 5-217 T

LINE ITEM NUMBER	EQUIPMENT DESCRIPTION	QUANTITY
461790	1/4-Ton Truck, Jeep	1
947016	3/4-Ton Dump Truck	24
-	Troops	35

TABLE XXXVI (U)
UNIT COMPOSITION –
105 MM HOWITZER BATTERY TOE 6-707 T

LINE ITEM NUMBER	EQUIPMENT DESCRIPTION	QUANTITY
418318	Howitzer 105 mm	6
461206	1/2-Ton Truck, Platform	1
461790	1/4-Ton Truck, Jeep	2
-	Troops	89

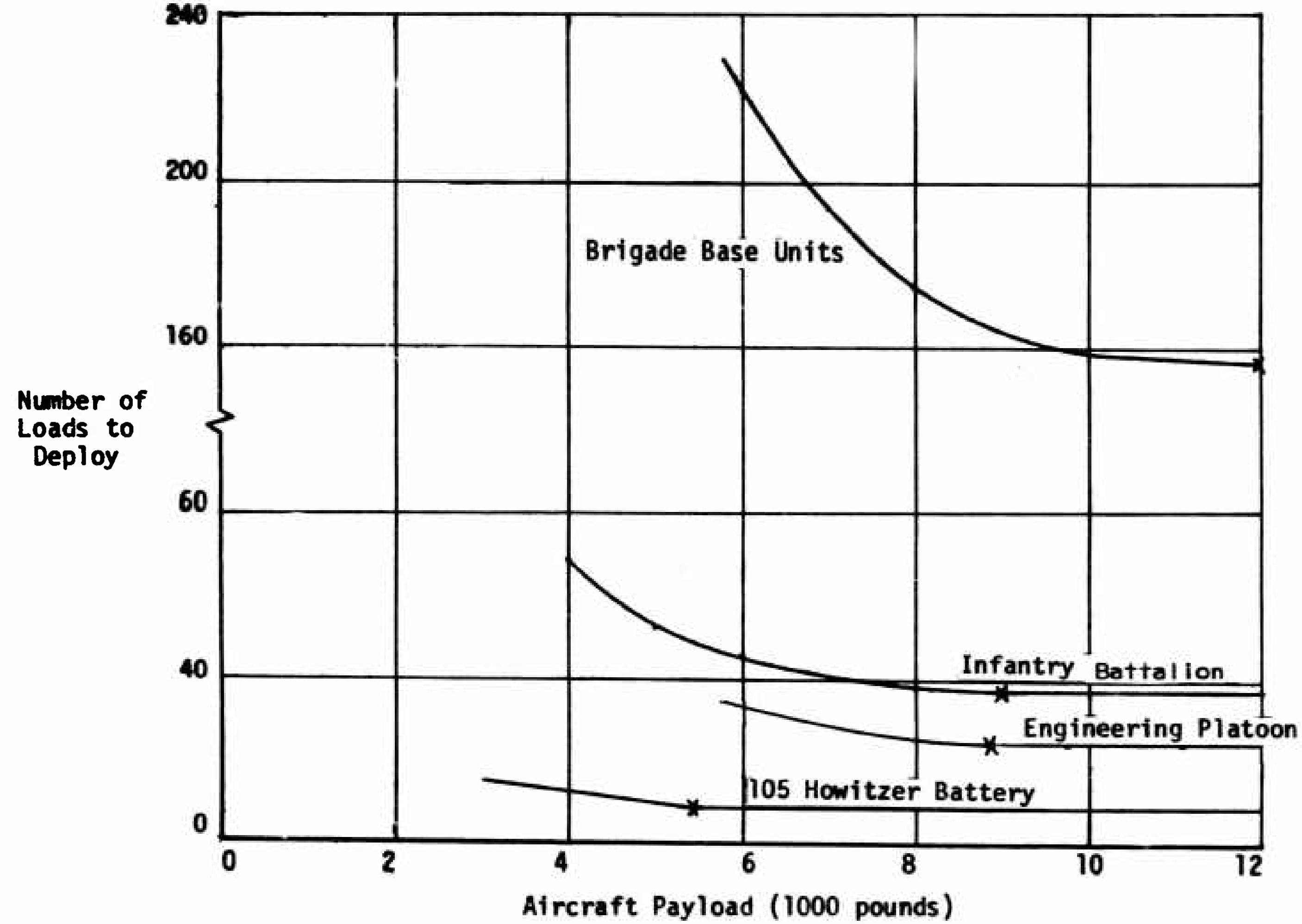


Figure 111. (U) Number of Loads to Deploy Typical Combat Units as a Function of Aircraft Available Payload.

TABLE XXXVII (U)
UNIT COMPOSITION – BRIGADE BASE UNITS*

LINE ITEM NUMBER	EQUIPMENT DESCRIPTION	QUANTITY
461790	1/4-Ton Truck	7
461790 + 457110	1/4-Ton Truck & 1/4-Ton Trailer	68
459832	1/4-Ton Ambulance	1
461206	1/2-Ton Truck	21
460050 + 457190	3/4-Ton Truck + 3/4-Ton Trailer	51
460080 + 457190	3/4-Ton Truck + 3/4-Ton Trailer	6
460050	3/4-Ton Truck Wo/Winch	1
460080	3/4-Ton Truck W/Winch	13
948910	Scooter	6
947016 + 457190	3/4-Ton Dump Truck + 3/4-Ton Trailer	1
-	Troops	1070

*Only vehicles which are transportable in the XC-142 are shown.

shown by the rising portion of the curve to the left of the X in Figure 111. It is interesting to note that if the volume limit was lifted, the number of loads would continue to decrease to the right of the X as payload increased.

The curves for the brigade base and the engineering platoon stop at a payload of 5800 pounds. This is because these units have a large number of 3/4-ton trucks which weigh 5800 pounds, and at this point the units effectively become outsized to the aircraft. Although the infantry battalion contains two 3/4-tons trucks, the curve is shown as continuous because the number of 3/4-ton trucks is small as compared to the total number of vehicles. The sensitivity of the aircraft to 3/4-ton trucks is demonstrated by the engineering platoon. For the infantry battalion, the two 3/4-ton trucks were assumed to be lighter weight vehicles, which weight could be adjusted to within the aircraft payload by off-loading cargo. In making this assumption, the cargo quantity has been maintained constant, and the sensitivity of aircraft efficiency to a unit with a preponderance of men is shown. The number of cycles as a function of payload shown in Figure 111 is combined with payload/radius curves for the various flight modes in subsequent sections of the report to make an economic comparison of the two systems.

(C) COST ANALYSIS: METHODOLOGY, RATIONALE, AND DATA (U)

(U) Cost and effectiveness evaluations assist policy makers in the complex decision process of selecting one or more military concepts that may be committed to development, procurement, and operational readiness.

These evaluations involve the development of criteria that quantify both the financial requirements and military capabilities of competing military systems. Two possible evaluation criteria are:

1. A fixed budget or financial limitation with a variable effectiveness.

2. A fixed effectiveness with cost as the dependent variable.

Both of these criteria require that the competing aircraft operate over the same time period.

(U) Decision making in the military begins with the total United States military budget at the Department of Defense level. This budget quantifies in dollars the total annual resources the United States intends to commit to the defense of the country. After the gross amount of this budget is determined, decisions concerning the effective use of these resources are required. As anticipated, the goal is to obtain the best feasible or maximum military power for a given budget. Once the military objectives are defined and the alternative solutions are considered, the advantages and disadvantages of each alternative are compared. For military aircraft, many decisions are made at various levels of command during the life of an aircraft. Assuming that an aircraft system is selected as the most effective and economical means of accomplishing a military objective, the decisions occurring during the life of this aircraft are similar to the following.

1. Which aircraft design or designs should be committed to research and development: Procured?

2. How many aircraft should be procured for each of its missions?

3. How many aircraft should be assigned to a particular theater, command, or division?

4. How should the field commander allocate his aircraft for maximizing military worth?

The answers to each of these questions are not mutually exclusive.

(U) In this evaluation, some of the decisions in the total decision process have already been made. It is assumed that a requirement for a fixed-wing V/STOL transport (an XC-142A type aircraft) has been established

for use by the Army, Navy, and Marines in missions such as: Army airmobile operations, Army combat support missions, Navy antisubmarine warfare, Navy carrier on-board delivery, Navy and Marine combat rescue missions, and Marine combat operations.

(U) The decision to begin development on the basic aircraft is assumed made, and a program office established, even though the final selection of a cargo handling system for the Army aircraft has not been determined. It is assumed that the Navy and Marine aircraft are designed with conventional aft doors and solid cargo floor. The Army configuration will have either the conventional or the vertical/modular cargo handling system installed during the production of the aircraft. The Army's decision is whether to install the conventional or the vertical/modular cargo handling system in its V/STOL transports.

(U) TOTAL PROGRAM COST

The total resources required to develop, produce and operate such a V/STOL transport are quantified in the total program cost. A total program cost includes the costs of all resources required by an aircraft system from initial conception to inventory phase-out. For this V/STOL transport, the total program cost includes expenditures for research, development, test and evaluation, investment and operations. Each branch of the service funds its own share of this total program cost.

The cost of the research, development, test and evaluation of the basic aircraft is to be funded equally by the Army, Navy, and Marines. Each service is responsible for the cost of procuring and operating its own aircraft. The average flyaway cost of the basic aircraft for all three services is based on the anticipated production quantity. In the initial program plan, it is assumed that approximately 900 aircraft will be produced during the life of the program with approximately 1/3 going to each service.

If follow-on aircraft are procured by the military, no additional development expenditures are required for additional identical aircraft, assuming the production line is still in existence. If modifications are required for follow-on procurement, additional development costs may be incurred by the new procurement.

(U) ARMY SHARE OF TOTAL PROGRAM COST

The Army is required to fund one-third of the basic aircraft research, development, test and evaluation (RDTE) costs, any additional expenditures required to develop and install the selected cargo handling system, plus the expenditures required to procure and operate its own aircraft. Thus, the Army's share of this V/STOL transport's total program cost is illustrated in Figure 112 and the following equation:

Missions

NAVY
- **Antisubmarine Warfare**
- **Carrier On-Board Delivery**
- **Combat Rescue**

MARINE
- Combat Operations
- Combat Rescue

ARMY
- Combat Support Operations
- Airmobile Operations

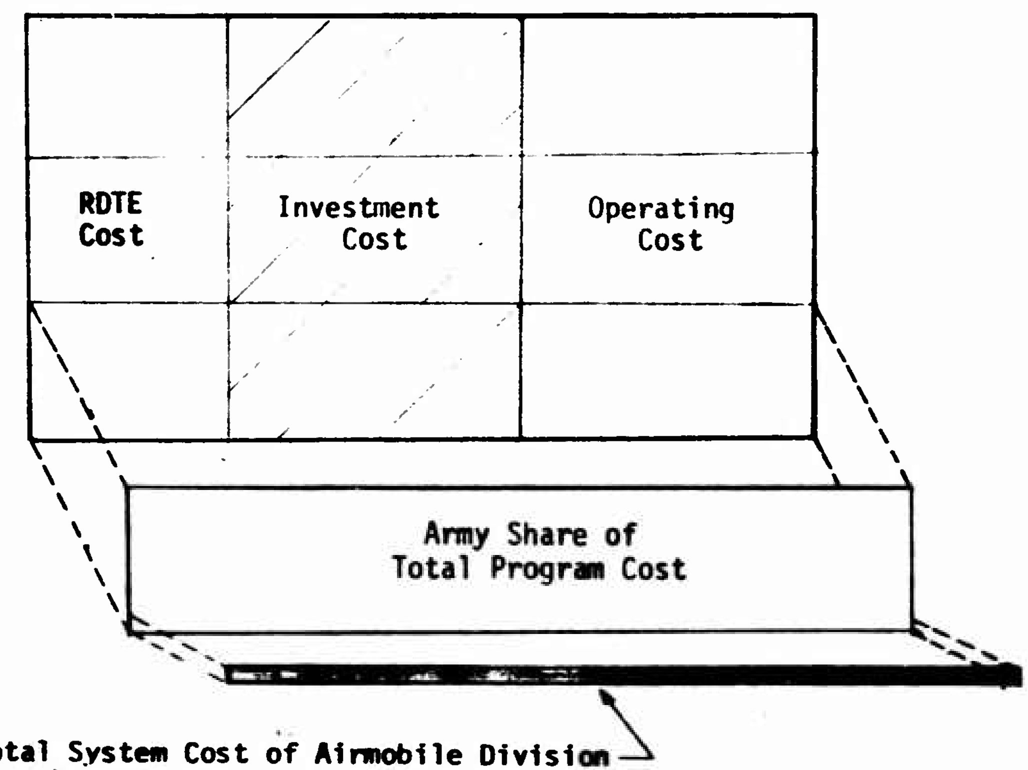


Figure 112. (U) Total Program Cost.

$$\begin{array}{c}33\text{-}1/3\% \\ \text{Basic Aircraft} \\ \text{RDTE} \\ \text{Cost}\end{array} + \begin{array}{c}\text{Cargo Handling} \\ \text{System} \\ \text{RDTE} \\ \text{Cost}\end{array} + \begin{array}{c}\text{Army} \\ \text{Investment} \\ \text{Cost}\end{array} + \begin{array}{c}\text{Army} \\ \text{Operating} \\ \text{Costs}\end{array} = \begin{array}{c}\text{Army} \\ \text{Share} \\ \text{Total} \\ \text{Program} \\ \text{Cost}\end{array} \qquad (2)$$

The purpose of this evaluation is to assist in determining the preferred cargo handling system design that should be brought to fruition for the Army. Even though the decision to procure this basic transport has been made, the decision to develop and procure either the conventional or vertical/modular delivery system has not been made. Before deciding which delivery system design, either the conventional or the vertical/modular, may be committed to development, these designs must be evaluated from the viewpoints of productivity and cost. This evaluation compares the conventional and vertical/modular delivery system designs on a cost and effectiveness basis. The results of this cost and effectiveness evaluation could assist the Army in the decision of "which delivery system to procure."

While the calculations are used to determine the impact of the resulting design and operational features of the two cargo handling systems upon the operating and investment costs, total system costs are displayed to provide perspective of the absolute magnitude of the resource implications. Incremental costs between the conventional and vertical/modular delivery systems are emphasized, with an estimate of the 10-year total system cost also presented so that the incremental differences can be viewed in light of the total costs of the systems.

(U) ARMY AIRMOBILE OPERATIONS

This cost and effectiveness analysis is based on the delivery systems supporting airmobile divisions located in different temperature/altitude environments. Each delivery system design is required to carry the same cargo, and thus the effectiveness is fixed for the evaluation with cost being variable. The funding to procure and operate the aircraft required to support these divisions, plus the pro rata share of the Army's research development, test, and evaluation expenditures, is called the total system cost as illustrated by the gray bar in Figure 112.

It is assumed that the result of the airmobile evaluation operation is consonant with the output of the other Army operations. Since both delivery systems carry equivalent cargo as described in the evaluation mission, the least total system cost delivery system should be selected for development on a purely quantitative basis. Qualitative factors could negate the selection of the least cost design. Among these "qualitative" factors which might subjectively be weighed are:

1. The importance of timely delivery to the forward area.
2. Enhanced survivability accruing from decreased exposure time.
3. Increased cycles due to lower payload range curves.

4. Changes in break bulk operations at forward area terminals.

5. Increased versatility, especially selective discharge of cargo.

6. Higher specific cargo delivery due to increased delivery accuracy.

Although the study considers these factors, alternative assumption. may be weighed more heavily in the final decision process.

(C) TOTAL SYSTEM COST

(U) The relevant dollar costs for the present purposes are the differences between the total costs of providing the level of effectiveness required, utilizing either the conventional or the vertical/modular system. Since the most sensitive costs are operating costs, in particular variable operating costs, these costs receive primary emphasis.

(U) Research, Development, Test and Evaluation Cost

It is assumed that this V/STOL transport is a completely new design. Consequently, the basic aircraft incurs those non-recurring research, development, test and evaluation expenditures considered normal for a new V/STOL aircraft. The non-recurring costs peculiar to the cargo handling system are incurred by the Army. This approach results in a realistic cost evaluation of the conventional and vertical/modular designs, for neither design is favored with inherited developmental assets. Five prototype aircraft are included in the test program. The total amount of this cost category is $120,000,000 for the basic V/STOL transport (Reference 128). The R and D costs for the two approaches are:

	Conventional	Vertical/Modular
Basic Development	$120,000,000	$120,000,000
Army Share (1/3)	40,000,000	40,000,000
Development V/M		4,600,000
Army R and D Funding	$ 40,000,000	$ 44,600,000

The preceding costs are estimates and do not necessarily represent actual expenditures of existing programs.

(U) Investment Cost

After the flight test and evaluation program of the aircraft is completed, and assuming that the results are favorable, the decision to procure production aircraft is made. This decision to begin production is based on the performance, weights, and capabilities that were proven in the test program. The total expenditures required to integrate a new

aircraft system into the military operational inventory are called the investment cost. This cost category includes expenditures for the following cost elements:

Aircraft delivery system

Ground support equipment

Initial spares and spare parts

Training

The magnitude of this cost category is a direct function of the quantity procured plus the provisioning for attrition losses. The Army completely funds the investment expenditures required to support the airmobile divisions.

(U) Aircraft Delivery System

The aircraft delivery system includes the airframe, engines, avionics, other equipment and cargo handling system. Cumulative average production learning curves were developed for the basic aircraft flyaway cost. These cost quantity curves are based on published data of present tilt-wing V/STOL transports with each data point converted to 1966 dollars. The cumulative average flyaway cost for the Army procurement is based on the total production quantity of 900 aircraft of which the Army will procure approximately 300 aircraft. The basic V/STOL transport flyaway cost is estimated to be $1,800,000 (References 15, 32, 42, 47 and 64). To this amount, the cost of the installed cargo handling system must be added.

The estimated cost of the installed conventional cargo handling system is $11,500 per aircraft as shown in Table XXXVIII, yielding an average flyaway cost for the V/STOL aircraft of $1,811,500 exclusive of research, development, test, and evaluation expenditures.

The estimated cost of the vertical/modular delivery system is based on the incremental cost of installing the new cargo handling system and removing the existing cargo floor. The $1,890,000 flyaway cost of the vertical/modular delivery system is developed in Table XXXIX.

For the evaluation of the two closely related alternatives, the investment cost category includes expenditures for the basic aircraft complement and excludes the cost of combat attrition replacement aircraft even though these are procured during the investment phase of the life cycle. Because of the relationship between the missions performed and the investment in attrition replacement aircraft required, the cost of attrition aircraft is considered a variable operating cost in examining the incremental cost differences between the conventional and vertical/modular systems. This accounting process simply recognizes the facts that (1) no losses occur if the aircraft is not flown, and (2) differing losses occur in performing different missions. With the cost of

TABLE XXXVIII (U)
CONVENTIONAL CARGO HANDLING SYSTEM
ESTIMATED INCREMENTAL PRODUCTION COST

(300 AIRCRAFT)

Roller Conveyors	$ 4,200
Buffer Boards (with Metal Facing)	75
Pendulum Release Mechanism	125
Anchor Cable	100
Static Line Retriever Winch	3,000
Installation	4,000
Total Incremental Cost	$ 11,500

TABLE XXXIX (U)
VERTICAL/MODULAR CARGO HANDLING SYSTEM
ESTIMATED INCREMENTAL PRODUCTION COST*

(300 AIRCRAFT)

Fuselage Structure	$ 1,800
Door Assembly (Incl Rollers)	24,000
Pallet Support and Release Mechanism	15,400
Ramp Roller Conveyor System	500
Door Latch and Actuating Mechanism	25,500
Hydraulic Control System	4,000
Electrical Control System	1,200
Computer	15,000
Barrier Net Fittings and Anchor Lines	300
Barrier Net	500
Cargo Restraint	1,800
Total Incremental Cost	$ 90,000

* Installation Included

attrition aircraft expressed in this manner, the effect of varying mission mixes on the system cost may be examined relatively easily.

In a wartime environment, aircraft losses may be significant and must be explicitly considered as a function of the missions performed. In the final summary, the lost aircraft costs are transferred from the operating to the investment cost category to reflect financial management implications of the alternative systems.

(U) Ground Support Equipment

Equipment required for maintaining and servicing the delivery systems at all maintenance echelons is included in ground support equipment. The cost of this equipment is a direct function of the quantity of aircraft operating at a specific location. It is assumed that both aircraft designs require similar support equipment and that no peculiar or unusual ground support equipment is required by the vertical/modular design. The cost of the ground support equipment is estimated at 5 percent of flyaway cost (References 42, 47, 58, and 64).

(U) Initial Spares and Spare Parts

The costs of the maintenance materials required to integrate the new delivery system into the Army inventory and to support the aircraft during the first year of operations are included in this cost element. Maintenance materials are a function of the aircraft complement and total aircraft procurement schedule. The cost of these maintenance materials is 22.5 percent of flyaway cost for both aircraft designs (References 42, 47, 58, and 64).

(U) Training

It is assumed that a complete training syllabus for the V/STOL transport will be developed and implemented prior to the introduction of this aircraft to operational forces. This cost element includes the cost of training equipment and personnel. The cost of the pertinent training equipment is estimated at 5 percent of the aircraft flyaway cost. It is assumed that the personnel assigned to this program have basic and specialty training. However, a significant cost is incurred in qualifying these personnel to maintain and operate this tilt-wing V/STOL transport. The costs of these training courses are based on data contained in the USAF Formal Training Course Costs chapter of Air Force Manual 172-3 (Reference 123) and are repeated in the following summary.

	Cost Per Man
Pilots	$17,000
Crew Chiefs	8,000
Maintenance Men	3,000

Thus, the investment cost for the aircraft required in this analysis includes the expenditures for the delivery system and all resources required to integrate these aircraft into the operational inventory. A comparison of the unit investment cost for both delivery systems shows the vertical/modular delivery system to be 4 percent more expensive per aircraft as shown in Table XL. The magnitude of this cost category is directly proportional to the size of the operational aircraft complement. The complement size is defined as a function of the anticipated employment scheme as developed later in this chapter. The complement size is determined as a function of a specific utilization, length of operating day and availability. After this complement size is determined, neither utilization nor cycles affect the investment cost.

The investment cost and the research, development, test, and evaluation costs are independent of the operational use of the delivery system once the investment has been made. Therefore, the investment part of the total system cost in the analysis is fixed regardless of the flight hours flown, the aircraft life, wartime use or peacetime use as long as the representative missions do not change. The representative wartime missions must be selected in light of the maximum missions the aircraft may be required to meet, but cannot always correspond with all of the maximum missions. As this study examines the XC-142A as primarily a resupply aircraft, the number of aircraft procured is based on a nominal sustained resupply mission selected in light of postulated maximum resupply requirements and also in light of possible deployment missions. The determination of the number of aircraft procured is discussed in the subsequent chapters. At this point it is important only to note that the selection is based on a nominal wartime mission, and that peacetime training and wartime operating costs are but projections at the time the investment is made.

(U) Operating Costs

The operating costs are a function of the employment of the aircraft and vary with flight hours, cycles, peacetime, wartime and conflict duration. Operating costs include expenditures required for the maintenance and operating of the delivery system after it is in the operational inventory. Both the conventional and vertical/modular delivery systems have a 10-year calendar life, and the total aircraft complement is in being for this 10-year period. The operating cost category covers a 10-year period. The field commander is responsible for the employment and subsequent maintenance of the aircraft once they are in operational status. Even though the field commander does have direct control over the employment of his aircraft, certain operating costs are incurred independent of his day-to-day decisions. These are called fixed operating costs. Other operating costs are directly related to the operational employment and are called variable operating costs. The operating cost is composed of several cost elements; some are fixed as a function of size of squadron and operational environment, and others vary with the actual employment scheme. The operating cost elements are:

Fixed Operating Costs:

Personnel pay and allowances

Overhauls

Variable Operating Costs:

Recurring spares and spare parts

Petroleum, oil, and lubricants

Lost aircraft

Lost cargo

Packaging, rigging, and parachutes

Fixed operating costs include expenditures for pay and allowances of the military and civilian personnel required to fly, maintain and support the delivery system. Once the complement and utilization are defined for support of the airmobile division, the total personnel requirements, both military and civilian, are also fixed.

(C) Personnel Pay and Allowances

(U) The personnel pay and allowances cost element includes expenditures for the basic pay plus all pertinent allowances the Army incurs for pilots, crew chiefs, military maintenance personnel, and military support personnel required to maintain and operate the delivery systems. Based on analysis of data contained in Congressional hearings, the following 1966 annual pay and allowance factors are used (Reference 51):

	Pay and Allowances per Year	Approximate Pay Grade
Pilots	$11,100	0-2/0-3
Crew Chiefs	5,700	E-4/E-5
Maintenance Personnel	4,500	E-4
Support Personnel	3,000	E-3

The crew, maintenance, and support personnel are directly proportional to the quantity of aircraft in a squadron.

(U) During wartime operations, the actual military personnel assigned to the aircraft complement is based on a 100 percent manning level. This manning level is defined as a function of anticipated average aircraft utilization during a wartime environment. Thus, the military personnel requirement is based on 100 percent manning of this aircraft complement.

The complement size is based on the capacity to meet a defined maximum mission. The goal is to have all personnel, or 100 percent manning requirement, on hand during a wartime environment. The personnel requirements for wartime operations appear in Table XLI. These data are based on Army and Air Force planning factors (References 122 and 123). The maintenance personnel are based on an average utilization of approximately four hours per day per complement aircraft.

(U) For peacetime operations, the maintenance and support manning level is estimated to equal 80 percent of the wartime requirements. This decreased requirement is due to lower peacetime utilization and lack of wartime surge requirements. Therefore, for a given quantity of aircraft required for an airmobile division, the peacetime maintenance and support personnel pay and allowance is equal to 80 percent of wartime costs. The same number of crew personnel are required for peacetime and wartime operations.

(U) These men are required to fly, maintain and support the delivery system and are located at the logistics support base at all times. These personnel are related to the complement size and do not vary with the utilization or cycles at a specific point in time. They are assigned to and therefore located with the aircraft whether the aircraft are in use or not in use. Consequently, for a given operational environment and aircraft quantity, the cost of military personnel is a fixed cost.

(U) Overhauls

This cost element includes the cost of civilians required for depot and major overhaul of the delivery systems. Overhaul maintenance materials are included in the recurring spares and spare parts category. One overhaul facility supports the aircraft of both divisions and is located in a secure area. The 2.1 men per aircraft required is based on prior Army studies (Reference 64). The overhaul cost element includes the pay for these civilians at an annual rate of $7,200. Even though the time interval between aircraft overhaul and major repair is often a function of utilization, the personnel required to perform this task must be available when needed. Consequently, the pay of these civilians is treated as a fixed operating cost element.

The total fixed annual operating costs are as a function of aircraft complement and an expected utilization level.

Variable operating costs include expenditures for recurring spares and spare parts; petroleum, oil, and lubricants; lost aircraft; lost cargo; and packaging, rigging, and parachutes. The amount of these expenditures is directly related to the operational employment of the system.

(U) Recurring Spares and Spare Parts

The cost of maintenance materials required at all echelons of aircraft maintenance is included in the cost element of recurring spares and

TABLE XL (U)

UNIT INVESTMENT COST COMPARISON

	Vertical/Modular	Conventional
Delivery System Flyaway	$1,890,000	$1,811,500
Ground Support Equipment	94,500	90,600
Initial Spares and Spare Parts	425,300	407,600
Initial Training	331,500	321,600
Total Investment Cost Per Unit	$2,741,300	$2,631,300
Relative Investment Cost Per Unit	1.04	1.00

TABLE XLI (C)

PERSONNEL REQUIREMENTS (U)

Crew [1]	Number of Men Per Crew	Crew Ratio	Assigned Men Per Aircraft
Pilots	2	2.0	4.0
Crew Chiefs	1	2.0	2.0
Total Men Per Crew			6.0
		Vertical/Modular	Conventional
Maintenance Personnel [2]		51	49
Support Personnel		11	11
Total Men Per Aircraft		68	66

[1] Same for both delivery systems.

[2] Reference 122 and 123

spare parts. The cost of the maintenance materials is a direct function of the flyaway cost. Utilization is the prime factor in determining the quantity of maintenance materials required by an aircraft. In wartime, high utilizations result in high spare parts consumption. Peacetime operations have lower utilization with a corresponding decrease in total spare parts consumption. It is assumed that the cost per flight hour is the same for peacetime or wartime operations. The estimated cost per flight hour for recurring spares and spare parts is $60 for the conventional system and $63 for the vertical/modular delivery system. The basic difference results from the unique features of the vertical/modular design.

(U) Petroleum, Oil, and Lubricants

The consumption of petroleum, oil, and lubricants (POL) is directly proportional to flight hours. The cost of POL at 1.56 cents per pound (Reference 123) includes all procurement and handling costs as per Air Force Manual 172-3. Since both aircraft designs have the same gross weight, they also have approximately the same fuel consumption rates. The fuel consumption is sensitive to the flight profile, temperature, and altitude.

(U) Lost Aircraft

Aircraft that are downed and not repairable are termed lost. The cost of replacement aircraft is included as a variable operating cost. The replacement costs of $1,811,500 for the conventional delivery system and $1,890,000 for the vertical/modular delivery system aircraft do not include crew losses. By segregating the lost aircraft cost as a separate cost element, the impact of vulnerability on the different delivery modes is apparent.

(U) Lost Cargo

The lost cargo cost element includes the weighted average cost of supplies that are dispatched from the logistics support base but are not received by either battalion or brigade units. Due to the variation in resupply requirement for brigade and battalion, a separate lost cargo cost is calculated for each unit. The average cost of cargo is calculated as per Table XLII. The costs include the cost of packaging, rigging, and parachutes that are lost during delivery. The different packaging requirements for the airdrop and hover-drop delivery modes require the use of four different lost cargo costs.

(U) Packaging, Rigging, and Parachutes

The cost of packaging, rigging and parachutes is a direct function of the delivery mode and amount of cargo carried. These costs are incurred primarily in hover-drop and airdrop delivery modes and are given in Table XLIII. The total cost per ton of supplies lost is given in Table XLIV. For the STOL-land and VTOL-land delivery modes, a normal rigging cost of $11.50 per ton of cargo delivered is incurred.

(U) The total system cost concept has been developed with the definition of and estimating relationships for each cost element. It is now possible to proceed with the derivation of the costs for each alternative for the various missions.

TABLE XLII (U)
LOST CARGO COST
BATTALION AREA

	Percent of Total*	Average Per Pound	Weighted Average Cost Per Pound
Class I	8.9	$ 0.40	$ 0.0356
Class II and IV	8.5	1.00	0.085
Class III	6.2	0.03	0.0019
Class V	76.4	0.70	0.535
Average Cost Per Pound of Lost Cargo			$ 0.6575

*Normal Combat Intensity

TABLE XLIII (U)
RIGGING, PACKAGING AND PARACHUTE COST
BATTALION RESUPPLY
DOLLARS PER PALLET

Delivery Mode	Airdrop		Hover-Drop	
Delivery System	Con	Vert/Mod	Con	Vert/Mod
A-22 Container	101	52	65	23
Descent Parachute[1]	556	556	-	-
Extraction Parachute[2]	16	-	-	-
Honeycomb Cushioning	5	5	5	5
Rigging	9	5	8	5
Pallet	10	10	10	10
Cost per Pallet	$ 697	$ 628	$ 88	$ 43
Cost per Pound of Cargo[3]	.4006	.361	.0506	.0247
Cost per Ton of Cargo[3]	801	722	101	49

1. G-12D parachute
2. 15-foot extraction parachute (1 per 6 pallets).
3. Based on average pallet weight of 1740 pounds.

TABLE XLIV (U)
TOTAL COST OF LOST CARGO
BATTALION AREA

	Rigging, Packaging and Parachute Cost Per Ton of Cargo*	Cargo Cost Per Ton	Total Cost Per Ton of Lost Cargo**
Airdrop			
Conventional	$ 801	$ 1,315	$ 2,116
Vertical/Modular	722	1,315	2,037
Hover-Drop			
Conventional	$ 101	$ 1,315	$ 1,416
Vertical/Modular	49	1,315	1,364

* 1,740 lb cargo per pallet
** Note: To use factor as presented, the weight of cargo lost should not include the weight of the rigging, packaging, and parachutes lost with the cargo.

(C) WARTIME EVALUATION MISSION (U)

(U) To compare the wartime performance of the conventional and vertical/modular delivery systems, their performance must be viewed in light of its sensitivity to several interrelated parameters. These parameters have been discussed in previous chapters. This chapter presents the specific cases and numerical values selected for this evaluation, as well as the underlying rationale.

(U) The subsequent sections of this chapter will develop sets of parameters which permit a reasonable assessment of:

1. Missions which are representative of those which the systems would be expected to encounter throughout their lifetime, and the associated variable operating costs.

2. The number of aircraft and personnel which must be available to meet some maximum mission, and the associated investment and fixed operating costs for the conventional and vertical/modular delivery systems.

3. A net measure of the overall expected operational performance of the two competitive delivery systems, and the associated 10-year total system costs.

(C) MAXIMUM VERSUS AVERAGE OPERATING CONDITIONS (U)

(U) Maximum operating conditions, or limiting values of the mission parameters, serve to:

1. Establish initial aircraft design requirements, primarily hover weight limits versus density altitude, aircraft volume, and aircraft payload weight, subjects not dealt with in this study.

2. Assist in determining the number of aircraft procured to meet some near-maximum mission, and thereby to define fixed costs.

(U) In contrast, average operating conditions are required to assess the operational performance, or more properly, the distribution of operational performances, over a wide range of mission parameters.

(U) Whereas the number of aircraft procured and the expected conflicts are primarily matters for experienced and informed military judgment, variable operating costs are more readily quantifiable, and receive primary emphasis in this analysis. Although analysis of the fixed costs is de-emphasized, detailed data is presented to allow selection of the number of aircraft based on any combination of the mission parameters discussed in this study.

(C) The comparison of the variable operating costs for the conventional and vertical/modular delivery systems is based on average operating

conditions, some examined parametrically, others by using several discrete cases. The use of average operating conditions avoids some of the worst-case-design distortion inherent in using maximum limiting values, especially for: radius, temperature/altitude, and airfield constraints.

(C) For a given aircraft design, variable operating cost is most sensitive to:

1. Radius
2. Airfield and landing zone availability
3. Temperature and altitude
4. Cargo transported (unit supplied or deployed)
5. Aircraft attrition rates
6. Delivery mode employed

(U) Parametric examination of the first two factors is provided. Factors 3 through 5 were included by using nominal case values based on the operational concept. All delivery modes previously defined were examined, the selection of each depending on the operation, military unit, and airfield availability associated with the particular case under consideration. Figures 113, 114, and 115 summarize the cases evaluated.

(C) UNIT SUPPORTED (U)

The airmobile division was selected as the military unit supported in this evaluation. This division is trained for operations in which aerial transportation is often the only feasible means. It is also equipped for such operations, having more radios, fewer heavy vehicles and heavy artillery, and substantial organic aerial transportation and aerially mounted firepower.

Specifically, the study considers resupply and deployment operations in support of two brigade areas, each containing one brigade base and three battalion areas. The airmobile division units assumed located at the brigade bases and in the battalion areas are listed in Appendix I.

(C) TYPE OF CONFLICT (U)

The analysis assumes a counterinsurgency-plus environment, with relatively unsophisticated enemy air defense weapons. Significant ground-to-air fire is assumed, but none larger than .50 caliber.

Contact with battalion-size and larger enemy units is assumed.

(U) COMBAT INTENSITY

For resupply operations, three combat intensities are considered: lull, normal, and maximum.

Lull is defined as a period of relative inactivity, with assumptions similar to those for peacetime training, except for a 100-percent manning level.

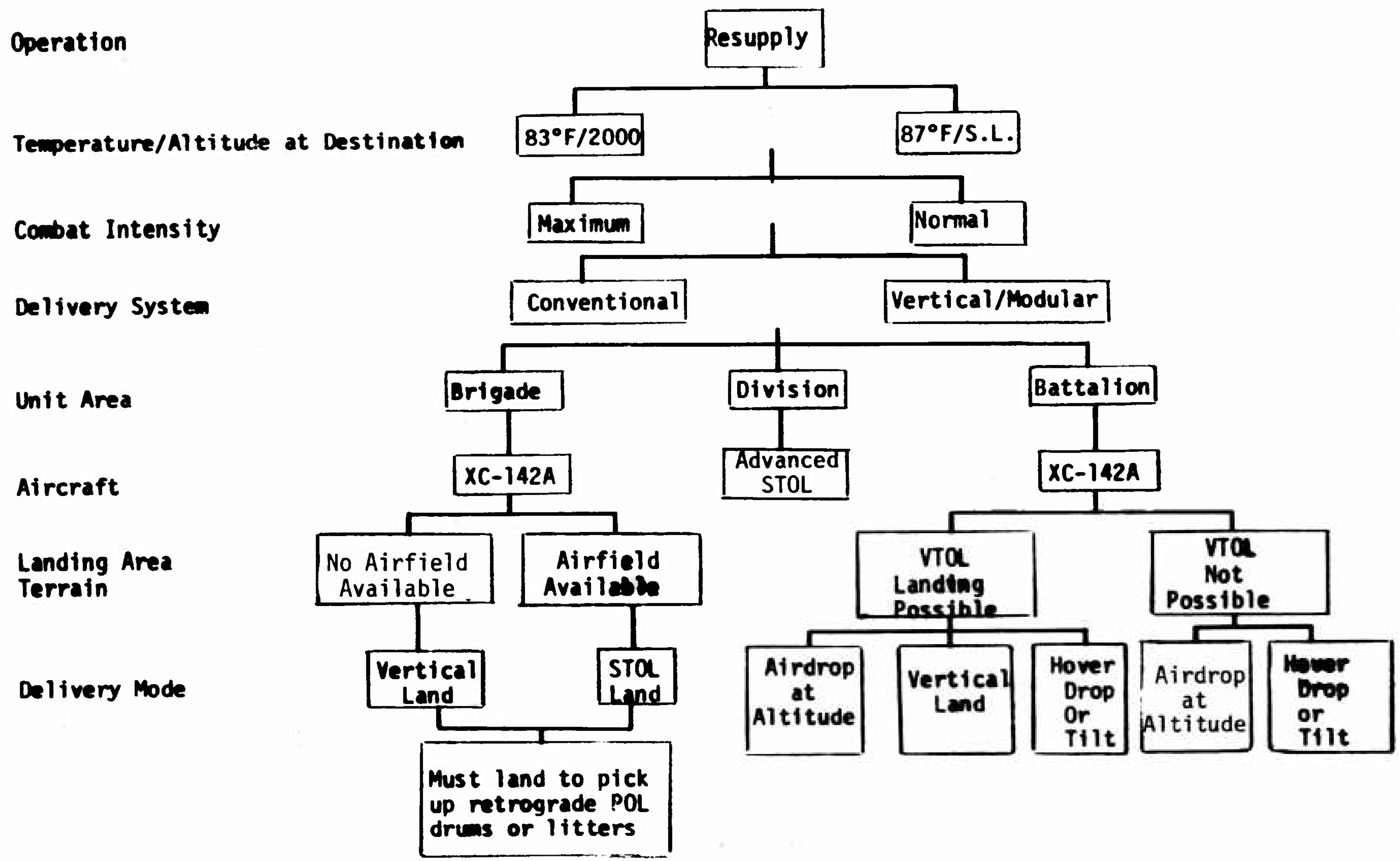


Figure 1i3. (C) Resupply Evaluation Cases. (U)

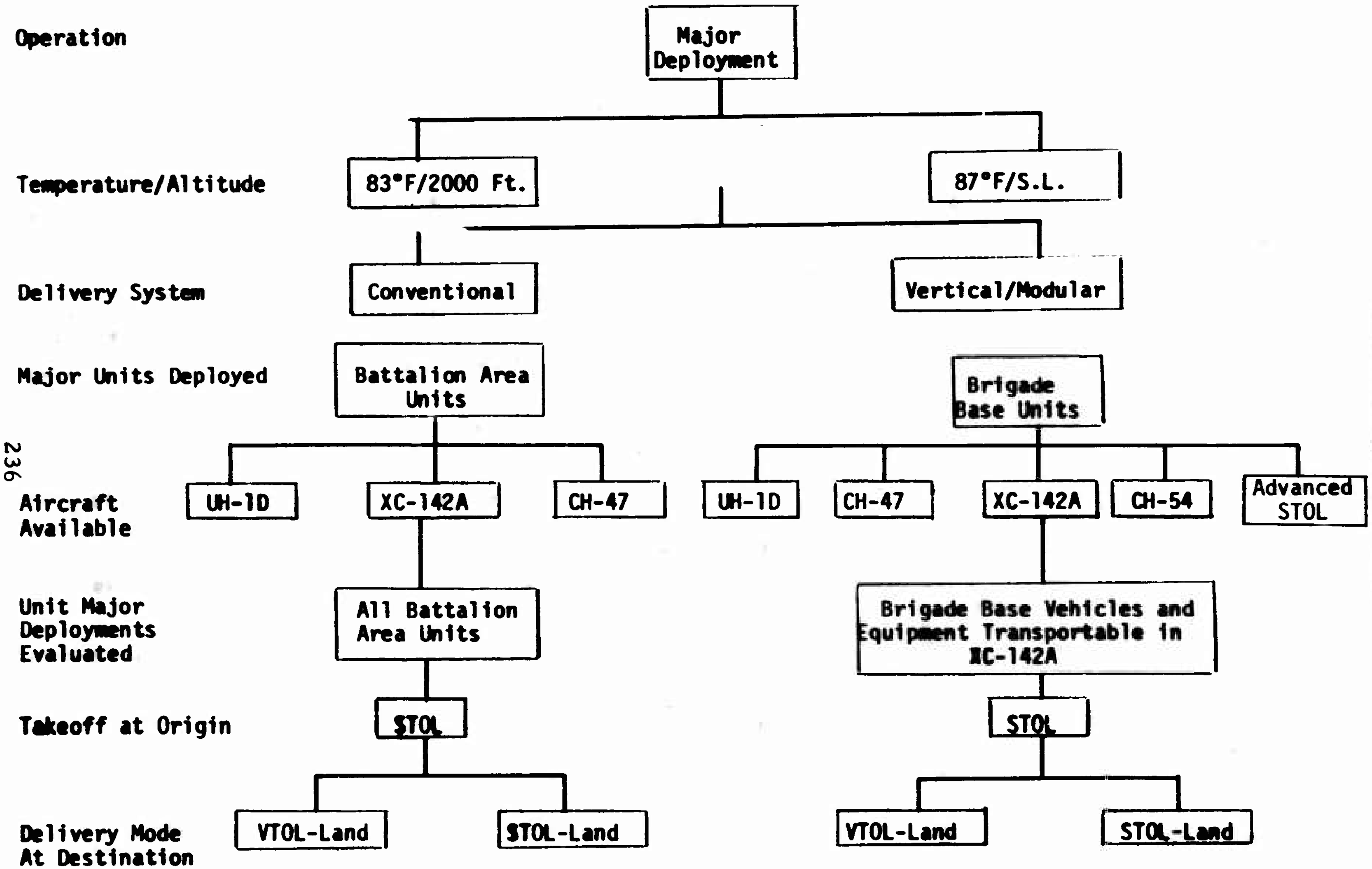


Figure 114. (C) Major Deployment Evaluation Cases. (U)

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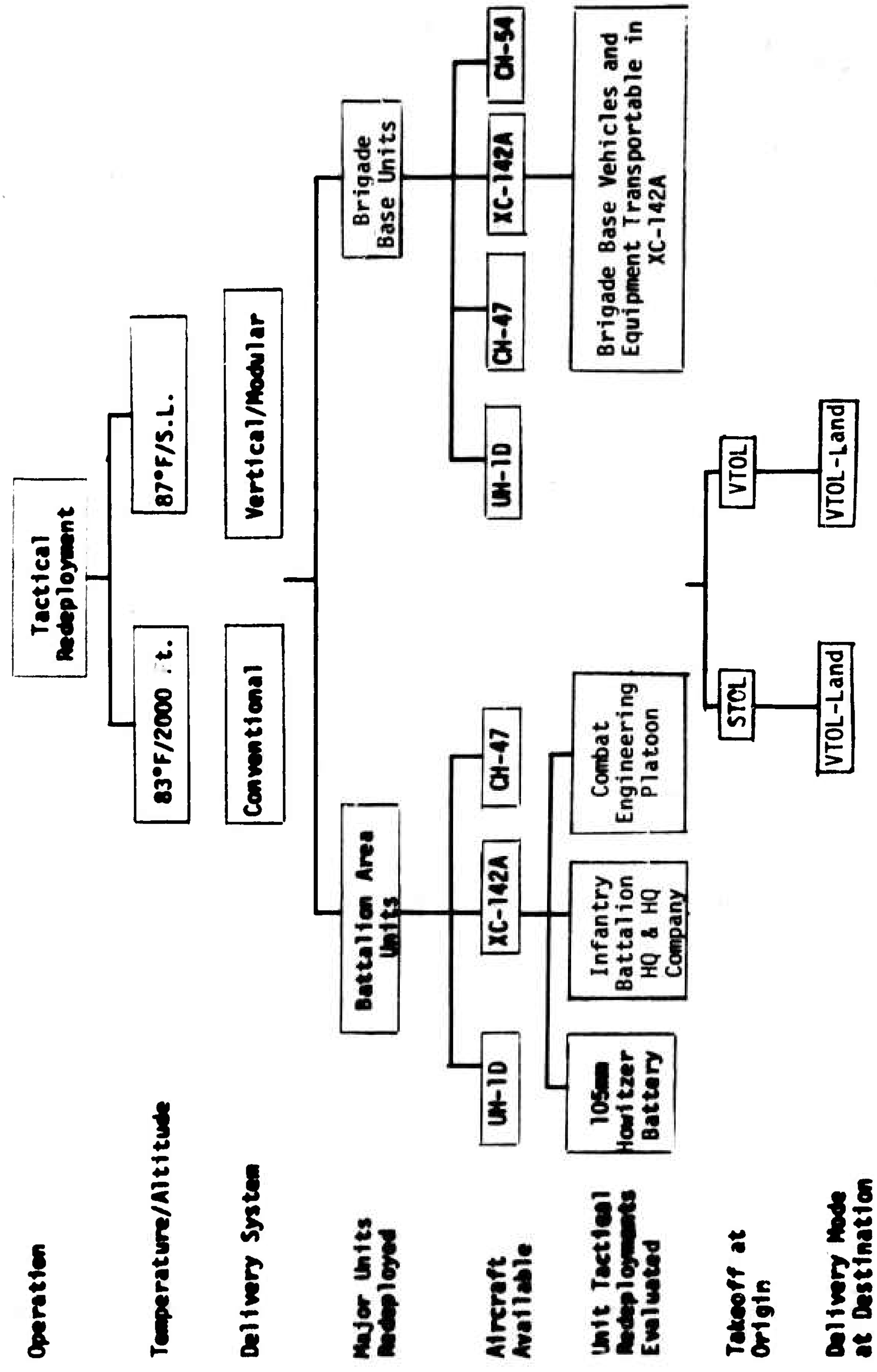

Figure 115. (C) Tactical Redeployment Evaluation Cases. (U)

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Normal combat intensity is defined as the most frequently encountered combat conditions for committed units, based on assumed "average" supply consumption and attrition rates.

Maximum combat intensity is designed as an approximation of ultimate resupply demands on the delivery systems considered. It also includes increased attrition rates due to enemy fire.

Combat intensity was not considered in evaluating the conventional and vertical/modular systems for deployment operations. Inherent in the definitions of major deployment and tactical redeployment are differences in aircraft vulnerability.

(U) CARGO TRANSPORTED

Units transported in deployment operations are discussed in the "Operational Comparison" chapter. Resupply consumption rates, quantities consumed, and the cargo transported are presented in Appendix I. Recognizing that there is no such thing as one normal or one maximum consumption rate, the rates assumed for the study are clearly defined in the Appendix.

(C) CASUALTY EVACUATION AND RETROGRADE CARGO (U)

(U) With some delivery modes, the aircraft inherently operate without landing (battalion area only), and return cargo cannot be loaded, as with airdrop and hover-drop. After delivering cargo using the hover-drop delivery mode, the aircraft could land to pick up return cargo. This was not assumed in the evaluation.

(C) Based on the response times in Gold Fire I (Page IV-20 of Reference 70) for picking up urgent and priority casualties being representative for wartime operations, brigade base helicopters are assumed to pick up most casualties in this evaluation. Not only do the response times appear shorter with this assumption in light of radii over which a direct resupply system operates, but the time from pickup to medical attention also appears shorter. Countering this reasoning is the possibility that the medical facilities at or near the logistic support base would be superior to those at the brigade or division base. Another possible disadvantage of not landing is that containers could not be recovered from the battalion area to deny their use to the enemy.

(C) Most fuel is delivered to the brigade base. Since the aircraft is always assumed to land at the brigade base, recovery of the 500-gallon fuel drums is not a problem.

(U) MULTIPLE STOPS PER CYCLE

The conventional system would require shifting cargo after each stop to remain within center-of-gravity limits. This is not necessary with the vertical/modular system. Since multiple stops are not necessarily required to resupply a battalion area, this would be an unfair imposition for the conventional delivery system.

Because of this difference, and because a generalized analysis of multiple stops in the battalion area would add little to this evaluation, multiple stops were not quantitatively evaluated. Adequate analysis of multiple stops would probably require a major simulation to obtain results proportional to the effort expended, a task beyond the scope of this study.

(C) AIRCRAFT LOSSES (U)

(C) The number of aircraft lost is an important cost element, but has a negligible effect on system performance if the availability of replacement aircraft is assumed. The loss rates used in this study were based on operating in the previously discussed "counterinsurgency-plus" environment and an interpretation of South Vietnam loss rate data (References 11, 17, and 124). The basic assumptions underlying the XC-142A loss rates shown in Table XLV are:

1. The number of aircraft downed by enemy fire on air-land assault missions is roughly ten times those lost on resupply missions if the aircraft unloading time is not excessive.

2. One aircraft per 10,000 cycles will be lost due to accidents, assuming accidents are more a function of takeoffs and landings than of flight hours.

3. 75 percent of the XC-142A's downed by enemy fire are lost, as compared to slightly less than 50 percent of the helicopters downed in South Vietnam.

4. Most exposure to enemy fire occurs in and around the delivery site.

5. The aircraft is exposed to enemy fire for about 4 minutes, including approach and landing when less than 30 seconds is spent unloading in the battalion area.

6. Net losses to enemy fire are the same for airdrop as for STOL-land or VTOL-land when landing in a relatively secure area, and are minimal.

7. Losses due to enemy fire only are double the normal values for resupply missions at maximum combat intensity.

(U) Since a detailed examination of aircraft losses was contractually prohibited, vertical/modular and conventional delivery system loss rates were conservatively assumed to be the same. No reduction in losses was accorded the vertical/modular system due to its being able to jettison resupply cargo if an engine is lost.

(C) THEATER OF OPERATIONS (U)

South Vietnam (plus some small areas of Cambodia, Laos, and North Vietnam immediately adjacent to South Vietnam) was selected as the

TABLE XLV (C)
ATTRITION RATES ASSUMED FOR NORMAL AND MAXIMUM COMBAT INTENSITY (U)

• Operation • Area • Delivery Mode or Flight Profile	Accidents Per 1000 Cycles	Number Exposures Per Cycle	Assumed Degree of Vulnerability Per Exposure	Loss Rate Per 1000 Cycles: Enemy Fire Only: Normal	Enemy Fire Only: Maximum	Accidents Plus Enemy Fire: Normal	Accidents Plus Enemy Fire: Maximum
Resupply	0.100	1	Low	.033	.066	.133	
Battalion Area							
Airdrop	0.100	1	Low	.033	.066	.133	.166
VTOL-land	0.100	1	High (+)	.160	.320	.260	.420
Hover-drop	0.100	1	High (-)	.080	.160	.180	.260
Brigade Base							
STOL-land	0.100	1	Low	.033	.066	.133	.166
VTOL-land	0.100	1	Low	.033	.066	.133	.166
Major Deployment							
STOL/STOL	0.100	1	Low	.033	-	.133	-
STOL/VTOL							
Bn Area Units	0.100	1	Very High	.800	-	.900	-
Bgde Base Units	0.100	1	Low	.033	-	.133	-
Tactical Redeployment							
STOL/VTOL							
Bn Area Units	0.100	2	Low/Very High	.833	-	.933	-
Bgde Base Units	0.100	2	Low/Low	.066	-	.166	-
VTOL/VTOL							
Bn Area Units	0.100	2	Low/Very High	.833	-	.933	-
Bgde Base Units	0.100	2	Low/Low	.066	-	.166	-

geographic area in which the airmobile division is deployed for this study. South Vietnam was chosen because it is representative of the areas of the world in which aerial transportation would be required to compensate for poor or non-existing surface lines of communication. The choice of South Vietnam offers significant amounts of data on vertically supported combat operations and also permits confirmation of many of the assumptions fundamental to the evaluation.

The theater of operation is defined as the area within 200 nautical miles of the three logistic support bases assumed, as shown in Figure 116. Two-hundred nautical miles is given in Reference 1 as the extended distance from the logistic support base to the battalion area. This figure illustrates the area within 100, 150 and 200 nautical miles of the three sea-supplied logistic support bases available in South Vietnam in 1960, prior to the buildup of U.S. forces.

Two major cases and many subdivisions of these major cases are evaluated. The first case is an airmobile division operating at random in the southern Mekong Delta portion of the area, the second an airmobile division operating at random across the northern portion as shown in Figure 116. Hereafter, these are referred to as the "87°F/sea level" case and the "83°F/2000 ft" case, essentially two hot-temperature cases, one lowlands, the other highlands.

As shown in Figures 117, 118, and 119, the two areas differ substantially in vegetation, terrain slope, and altitude. While altitude has an overall effect on aircraft performance, terrain and vegetation do not. Heavy vegetation and/or unfavorable terrain slopes make vertical assault operations more difficult since a large clearing is required to discharge many troops at one time. This same vegetation may or may not present a severe impediment to vertical resupply operations, depending upon the number of clearings available in the area in which the troops are deployed.

While the wet and dry seasons present a severe impediment to surface movement, their quantifiable effect on aircraft operations was not considered substantial enough to merit consideration in this evaluation, except as the wet and dry seasons affect brigade area airfield and landing zone availability. The probability of an aircraft being able to operate was assumed to vary, but not substantially, between the wet and dry seasons.

(C) This evaluation will use data from South Vietnam whenever applicable, but deviates from South Vietnamese experience in order to establish "nominal" evaluation cases appropriate to the direct resupply system concepts which are the subject of this study. Conclusions about future vertical deployment and resupply concepts cannot be based on past experience alone for several reasons:

1. There is no large and truly STOL aircraft in the current inventory.

2. There is no V/STOL aircraft in the current inventory.

3. Current rotary-wing VTOL craft are range-limited.

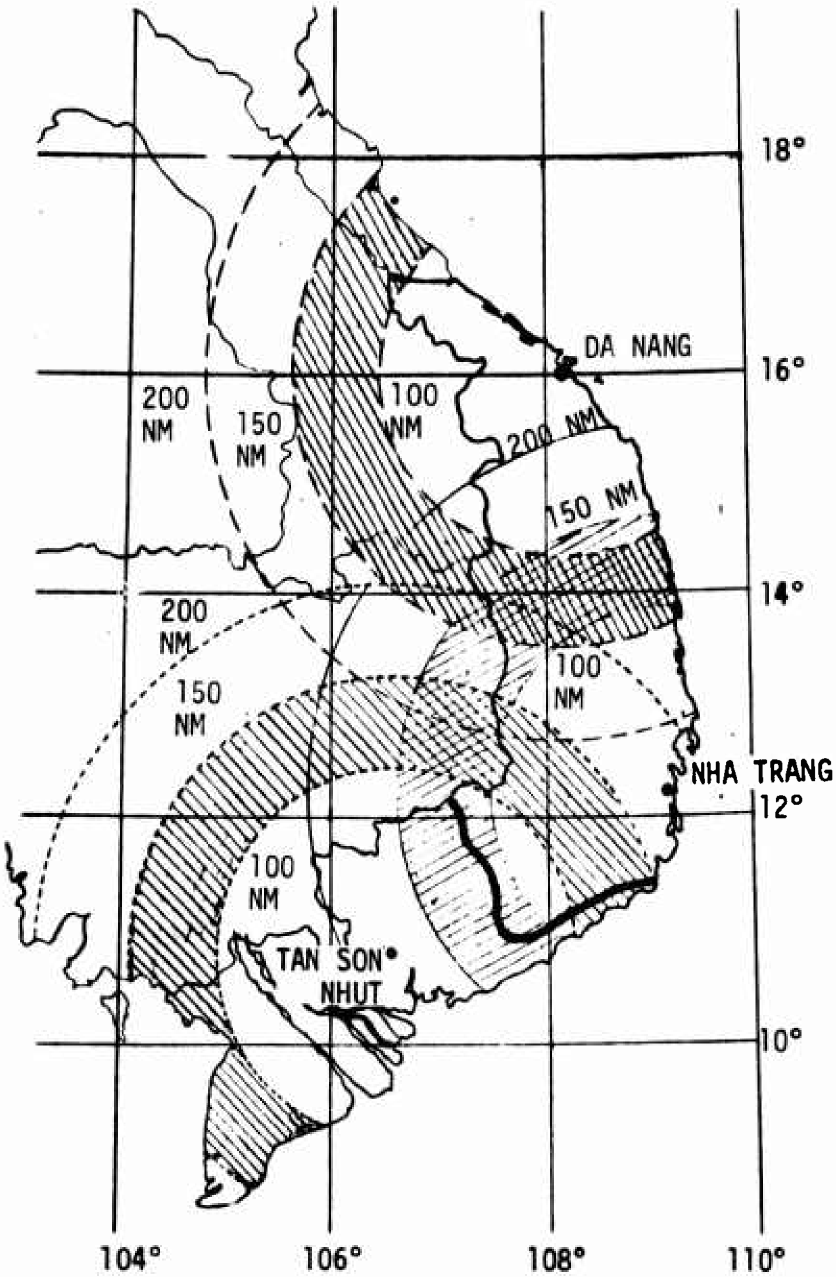

Figure 116. (C) Hypothetical Operating Area Defined by Three Logistic Support Bases Selected. (U)

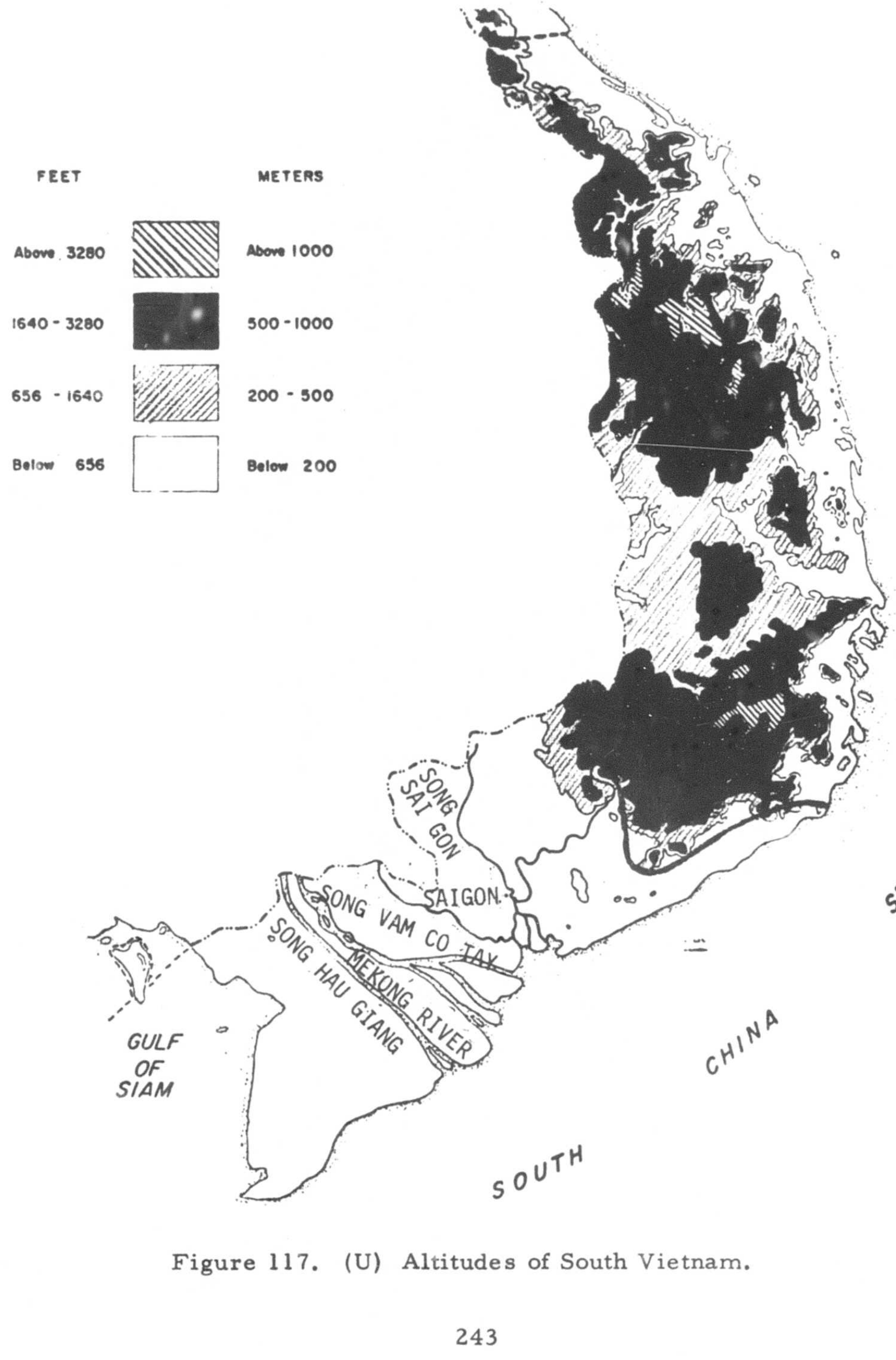

Figure 117. (U) Altitudes of South Vietnam.

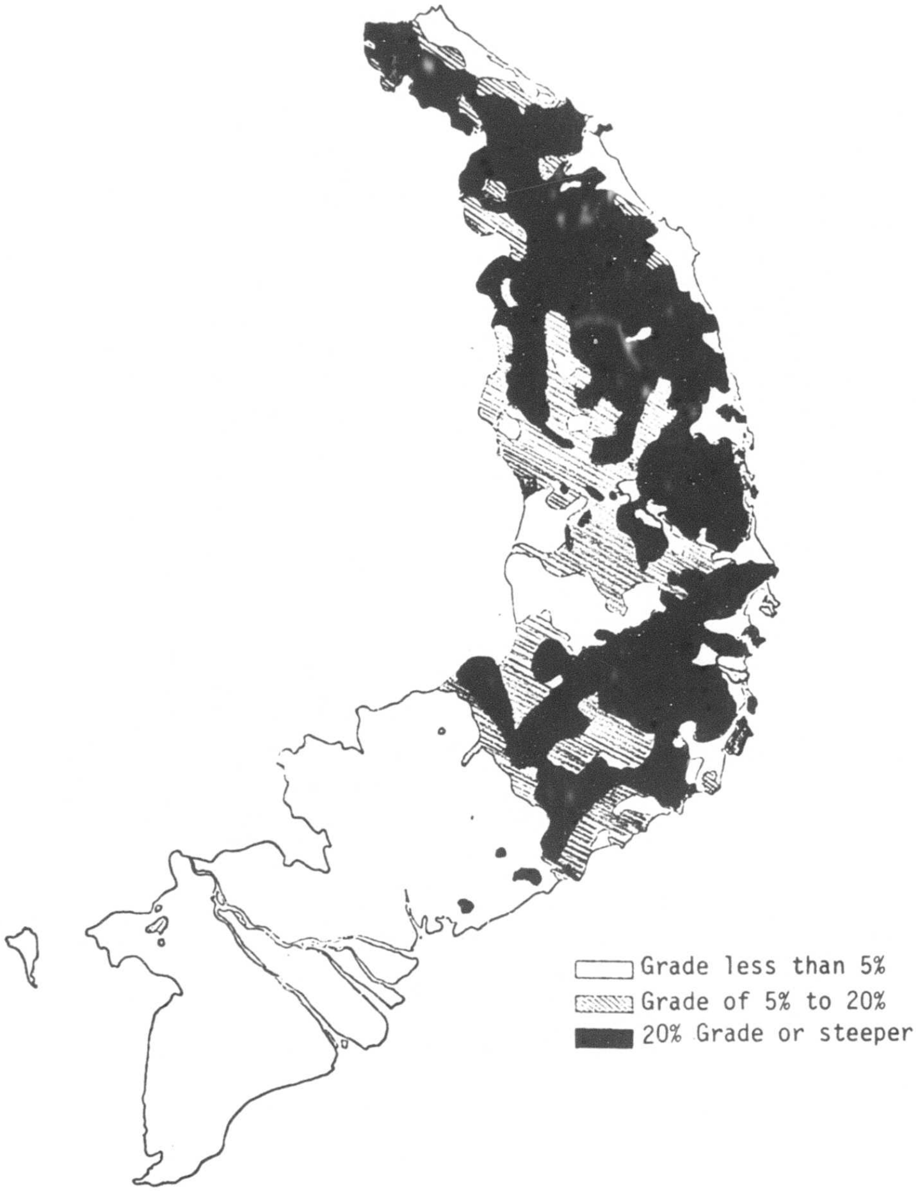

Figure 118. (U) Terrain Slopes of South Vietnam.

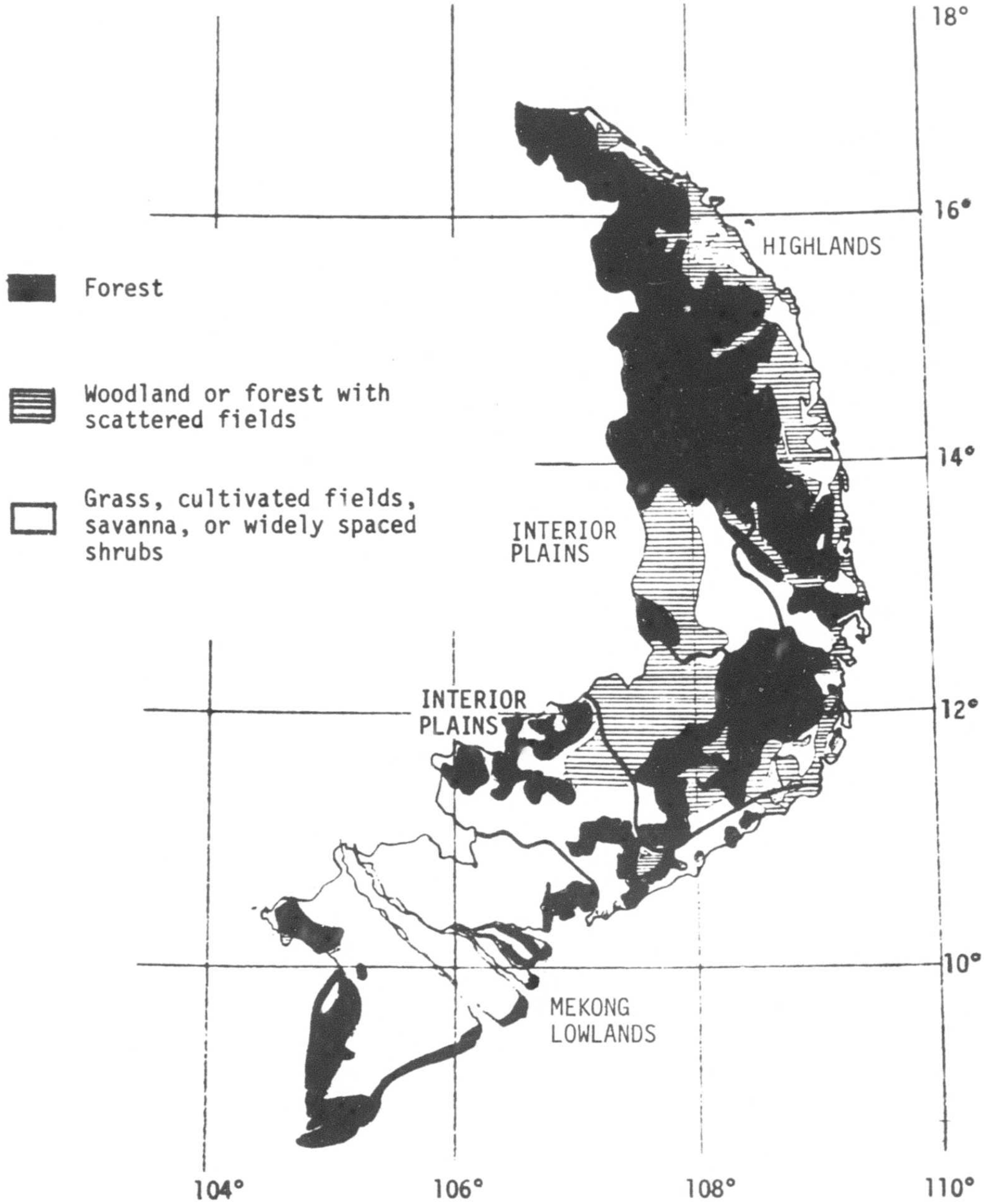

Figure 119. (C) Vegetation of South Vietnam. (U)

4. Most past and current helicopters with the notable exceptions of the CH-47 and CH-54, both of which must be classed as recently entering the inventory, have not been capable of handling large loads of palletized cargo, vehicles, and 500-gallon fuel drums.

While the Marines have employed vertical assault for some time, intentional sustained aerial support of large inland combat operations is recent doctrine. The first Army airmobile division came into being officially in mid-1965. The tactics of vertically supported combat operations may be expected to evolve steadily as vertical/lift and high/lift technology continue to advance, most probably at an increasing rate.

(C) Altitude (U)

Figure 120 shows the distributions of altitude for South Vietnam, for Thailand, and for what was once known as Indochina (Laos, North Vietnam, South Vietnam, and Cambodia). The altitude distributions are also shown for the generic areas classed as lowlands and as highlands for the three regions. The similarity between the three plots is evident.

(C) Temperature and Altitude (U)

The variation of temperature with altitude in South Vietnam is shown in Figure 121. This data is for periods of up to 47 years, collected at the weather stations detailed in Figure 122.

The temperatures plotted are monthly averages of the mean daily maximum temperature, since the aircraft would operate during the heat of the day. In addition to the trend of the annual average mean daily maximum temperature, confidence limits are shown in the lower quadrant, using the values for the coolest and hottest month. The absolute maximum temperatures recorded at the various station altitudes are plotted, but are unacceptable for analytical purposes since they are extreme values and information about their frequency of occurrence was not available.

Temperatures vary somewhat between the wet and dry seasons, but not so substantially as to affect the validity of the "nominal" or average temperatures assumed for this evaluation.

(C) Temperature/Altitude Cases (U)

Based on Figure 121, an 87°F average temperature was assumed for combat operations in the lowland area. Since most of this area is at or near sea level, 87°F/sea level became one of the cases evaluated.

Altitudes in the mountainous region vary from sea level to 5000 or 6000 feet. While some points exceed this altitude, their occurrence is rare, and combat operations at these altitudes are unlikely.

Figure 123 illustrates, but does not rigorously derive, the second temperature/altitude case, 83°F/2000 ft, for the mountainous or highland region. The altitude band in the upper left-hand quadrant is based on

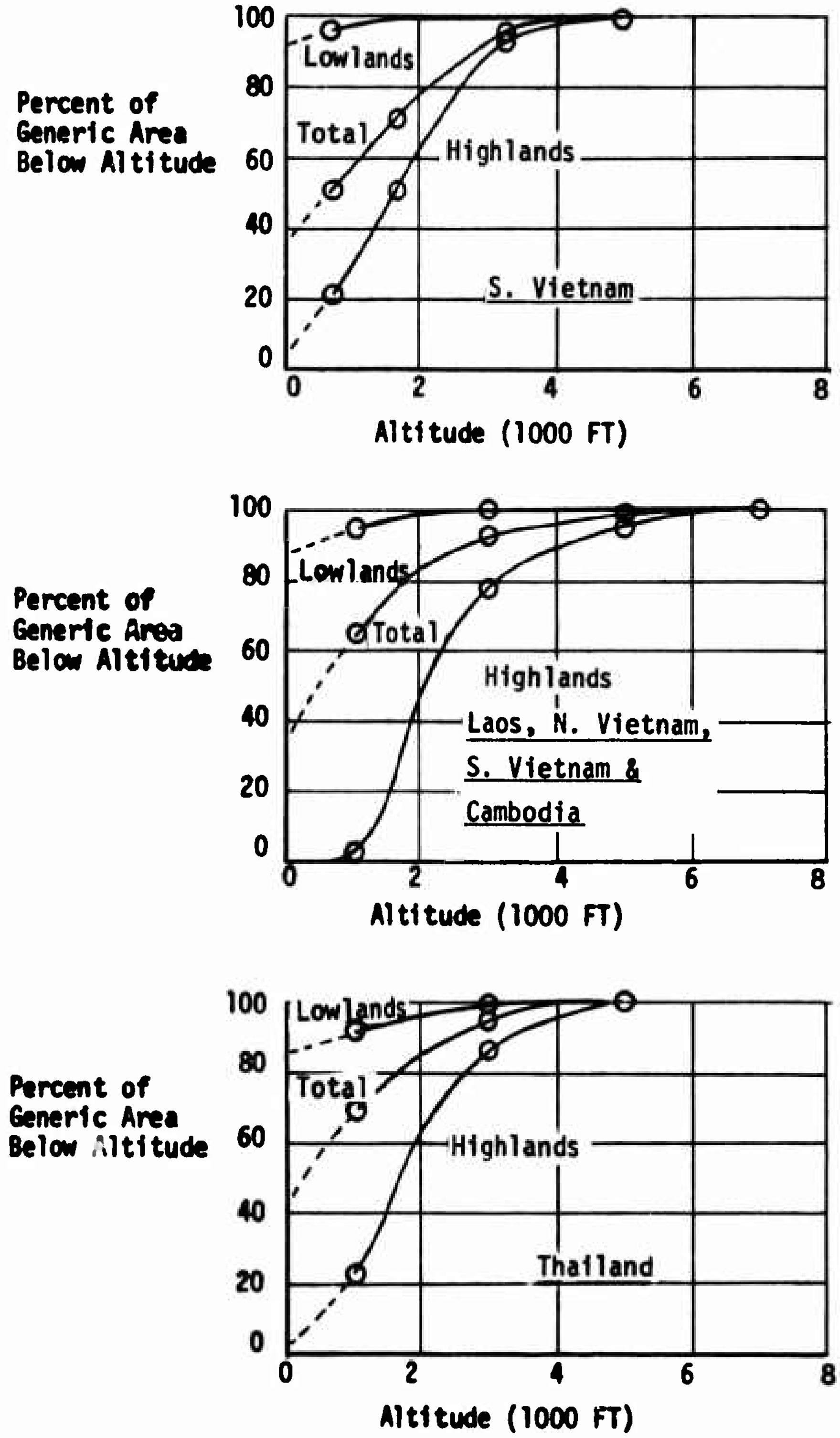

Figure 120. (C) Altitude Trends for Lowland, Highland, & Total Areas of Theater Operations and Adjacent Regions. (U)

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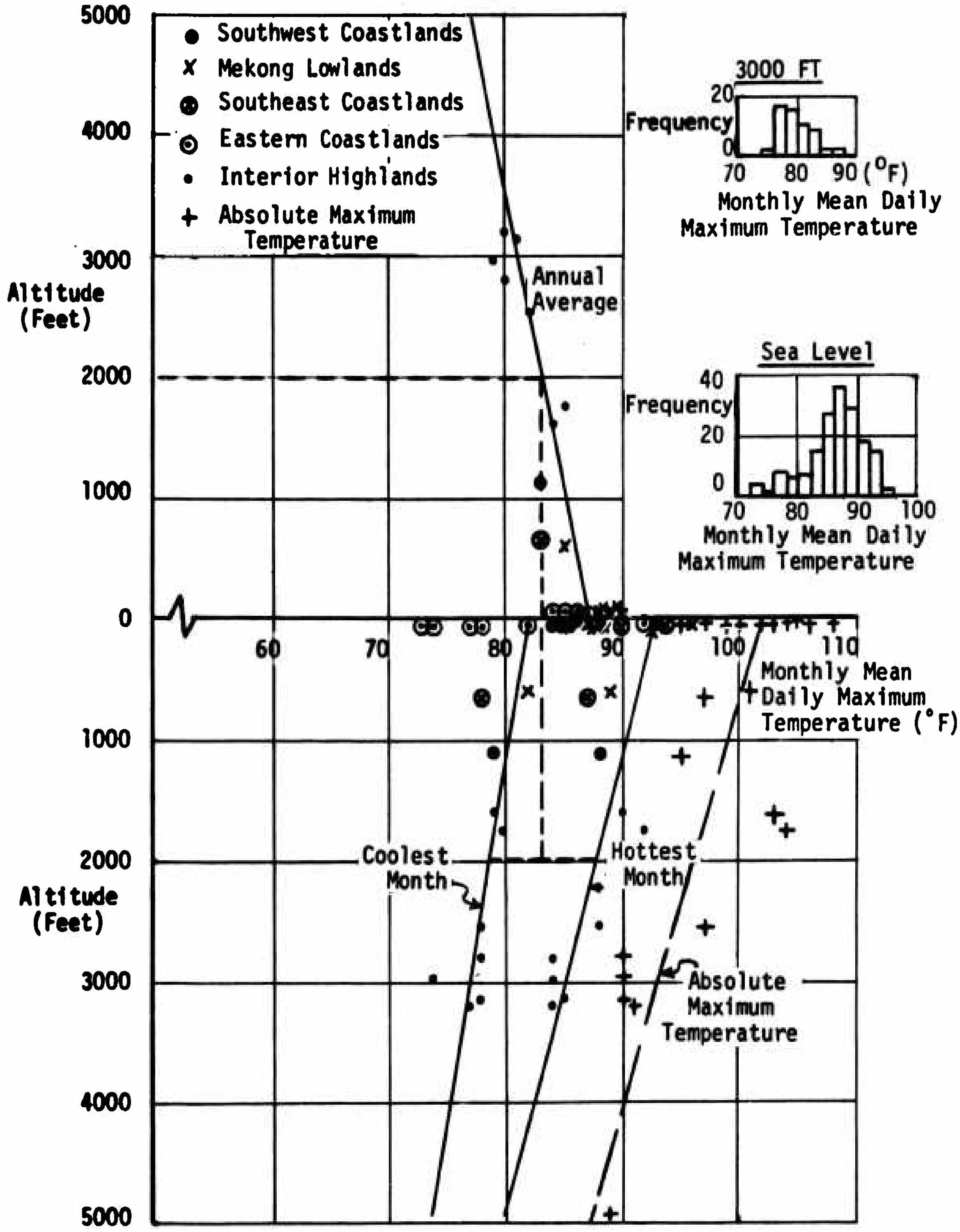

Figure 121. (C) Mean Daily Maximum Temperature Versus Altitude For South Vietnam; Annual Average, Coolest Month and Hottest Month; Absolute Maximum Temperature. (U)

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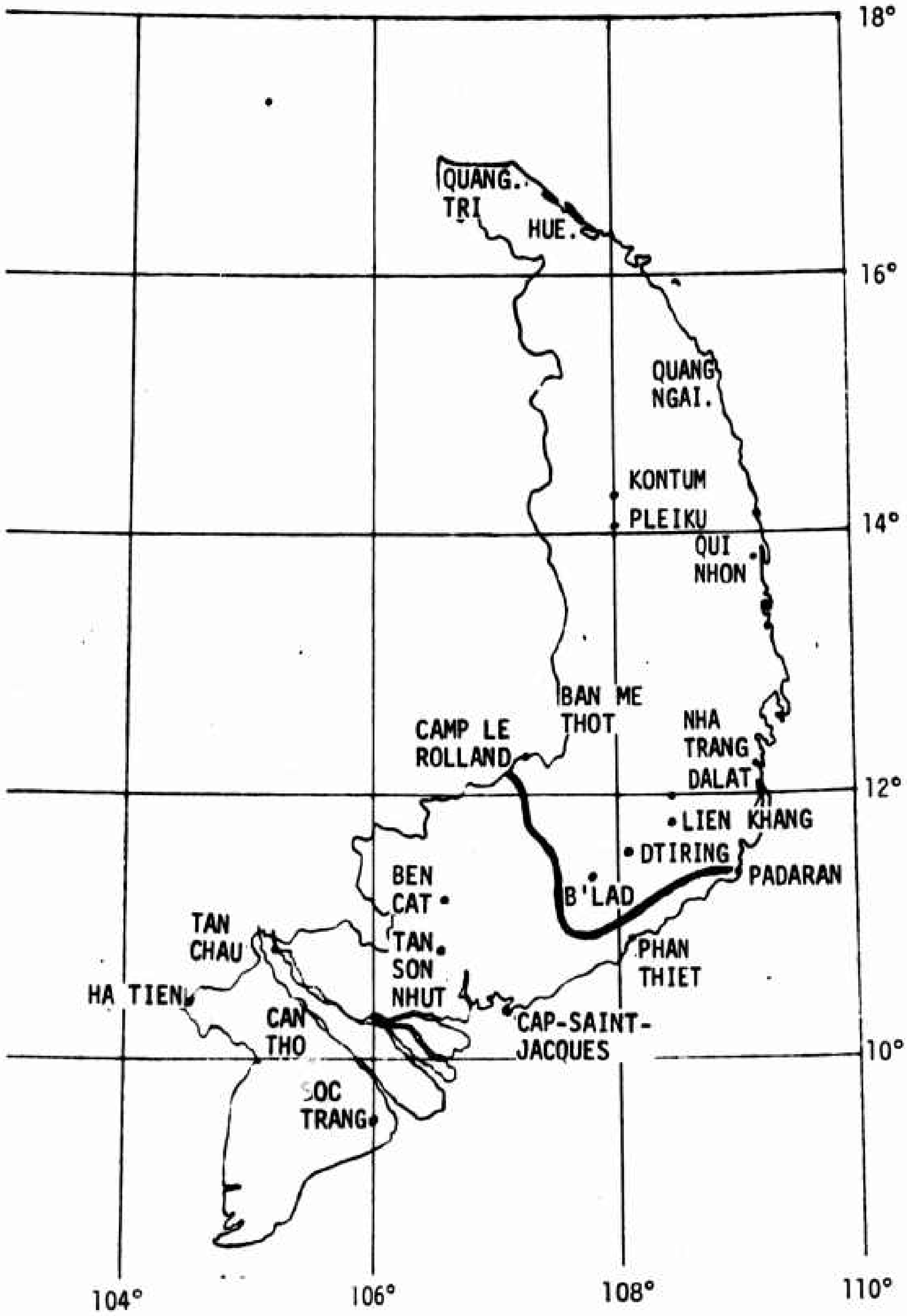


Figure 122. (C) Weather Stations Included in Temperature Data. (U)

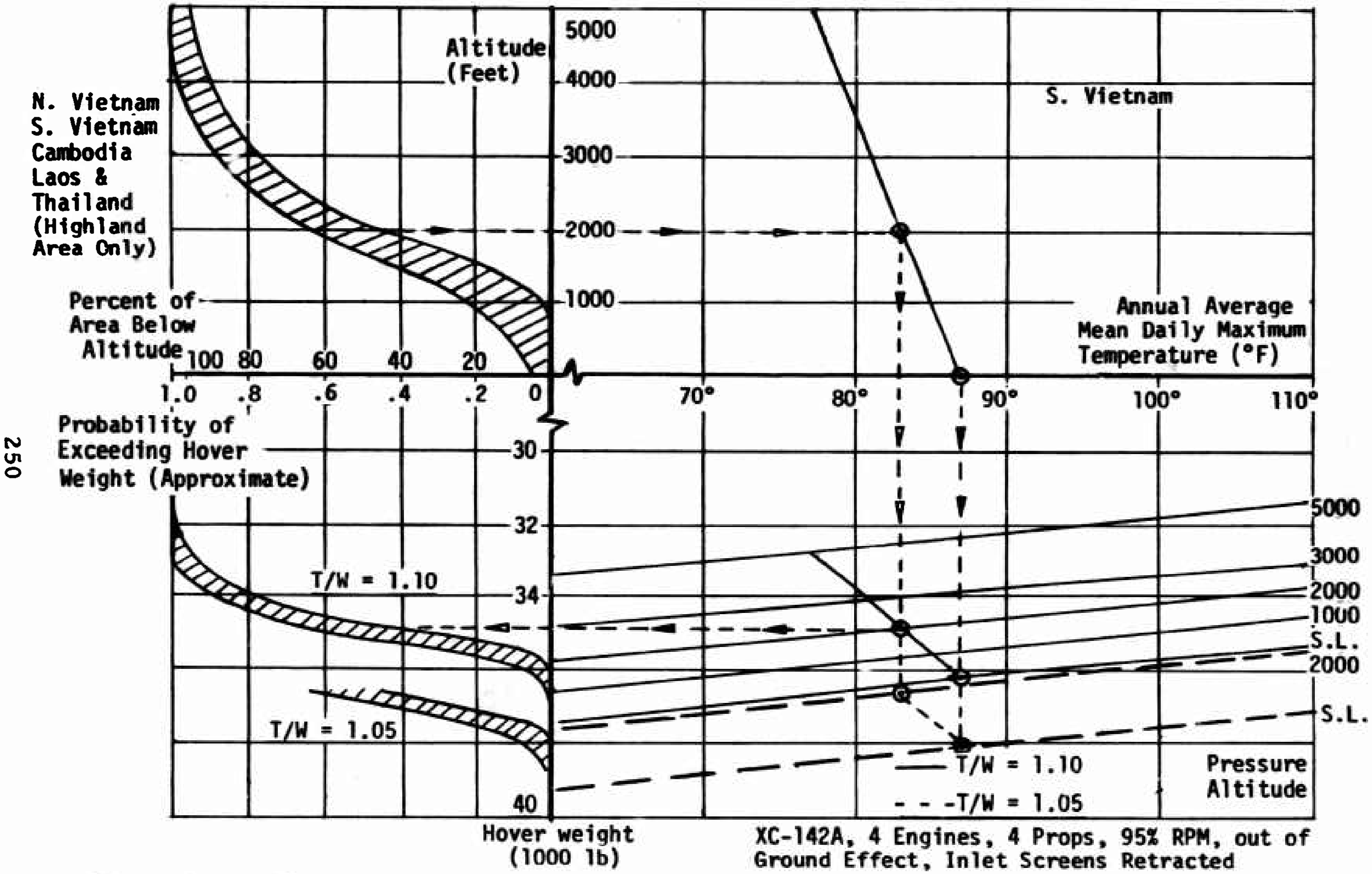


Figure 123. (C) Illustration of Highland Region Mean Operating Conditions for Highland & Mountainous Area Considered. (U)

Figure 120, including Thailand. Assuming that the South Vietnamese temperature data is representative of all three regions for which altitudes are shown, the evaluation could be considered applicable to the entire area. This evaluation assumes only that the South Vietnam temperatures are representative of the regions within 200 nautical miles of the three logistic support bases. Combining the altitude trend in the upper left with the temperature trend from Figure 121 shown in the upper right, then translating this temperature/altitude through the curves for the XC-142A in the lower right, yields the approximate distribution of hover weights expected. This distribution of hover weights is shown in the lower-left quadrant.

These average operating temperature/altitude cases are used to obtain an average hover weight, or conversely an average payload, since the aircraft weight on the return flight is approximately the same for any hover weight in the range of interest. Using 95°F/3000 ft instead of 83°F/2000 ft for the highlands region, for example, would decrease aircraft payload by roughly 1300 pounds when hovering at the mission midpoint. The decrease in payload would be roughly 2500 pounds if 95°F/3000 ft were used in place of 87°F/sea level for the lowlands region. This would magnify the percentage decrease in payload due to cargo handling system weight, the magnification increasing as radius increases and payload decreases. For VTOL/VTOL tactical redeployments, the distortion would be greatest.

(C) Airfield and Landing Zone Availability (U)

No airfields are assumed usable in the battalion area, even for an aircraft with the STOL performance of the XC-142A.

Airfields are assumed to exist 100 percent of the time at maximum combat intensity at the brigade base, and 93 percent of the time at normal combat intensity.

Analysis of the percents of the lowland and highland regions within a radius of an airfield depends upon which airfields are considered both available and suitable for use. Since a detailed examination was beyond the scope of this study, the above values were assumed. The values are conservative in favor of the conventional delivery system. References 36 through 40 are suggested as a starting point for extending this portion of the analysis.

Based on subjective judgment, made in light of Figures 116, 117, 118 and 119, an area suitable for a vertical landing was assumed to be available in the battalion area 100 percent of the time at maximum combat intensity, and 100 and 87 percent of the time at normal combat intensity in the 87°F/sea level and 83°F/2000 ft regions, respectively.

(C) CALCULATIONS: VARIABLE OPERATING COST (WARTIME) (U)

(U) Except for fixed costs dependent upon the number of aircraft procured, variable operating cost includes the incremental cost differences between the conventional and vertical/modular delivery systems. Variable operating cost is also the major variable in the 10-year total system cost, all other costs being aircraft-dependent. This chapter explains the procedure for calculating variable operating costs for the resupply and deployment missions shown in Figures 113, 114, and 115 in the "Wartime Evaluation Mission" chapter. Figure 124 illustrates the flow of variable operating cost calculations.

(U) Variable operating cost calculations were made separately for three operations (daily resupply, major deployments, and tactical redeployments) in accordance with the previously described operational concept and evaluation mission descriptions. The numerical results are tabulated in Appendix II. Only graphical results and summary tables are presented in the text. The results and basic input data are tabulated in a manner designed to permit:

1. Examination of the contribution of any major cost element to the total variable operating cost.

2. Extension of the analysis by varying the cargo transported, mission radius, aircraft losses, cargo losses, or criteria selected for determining the number of aircraft required.

3. Alteration of the mix of operations, delivery modes, and combat intensities necessary for obtaining a composite 10-year total system cost.

(U) Although quite different from the point of view of the underlying assumptions which are basic to a study of this type, resupply and deployment operations are similar from a calculations viewpoint. Resupply and deployment calculations differ basically in the manner in which the number of cycles required is determined.

(C) Mission Definition Parameters (U)

(C) As shown in the upper left-hand corner of Figure 124, each variable operating cost calculation is made for a given combination of:

1. Delivery system (conventional or vertical/modular).

2. Delivery mode (resupply) or flight profile (deployment).

3. Military unit (supplied or transported).

4. Combat intensity (normal or maximum) or type deployment (tactical or major).

Delivery System ____________

Delivery Mode ____________

Military Unit ____________

Combat Intensity ____________

Operating Radius ____________

Temperature/Altitude ____________

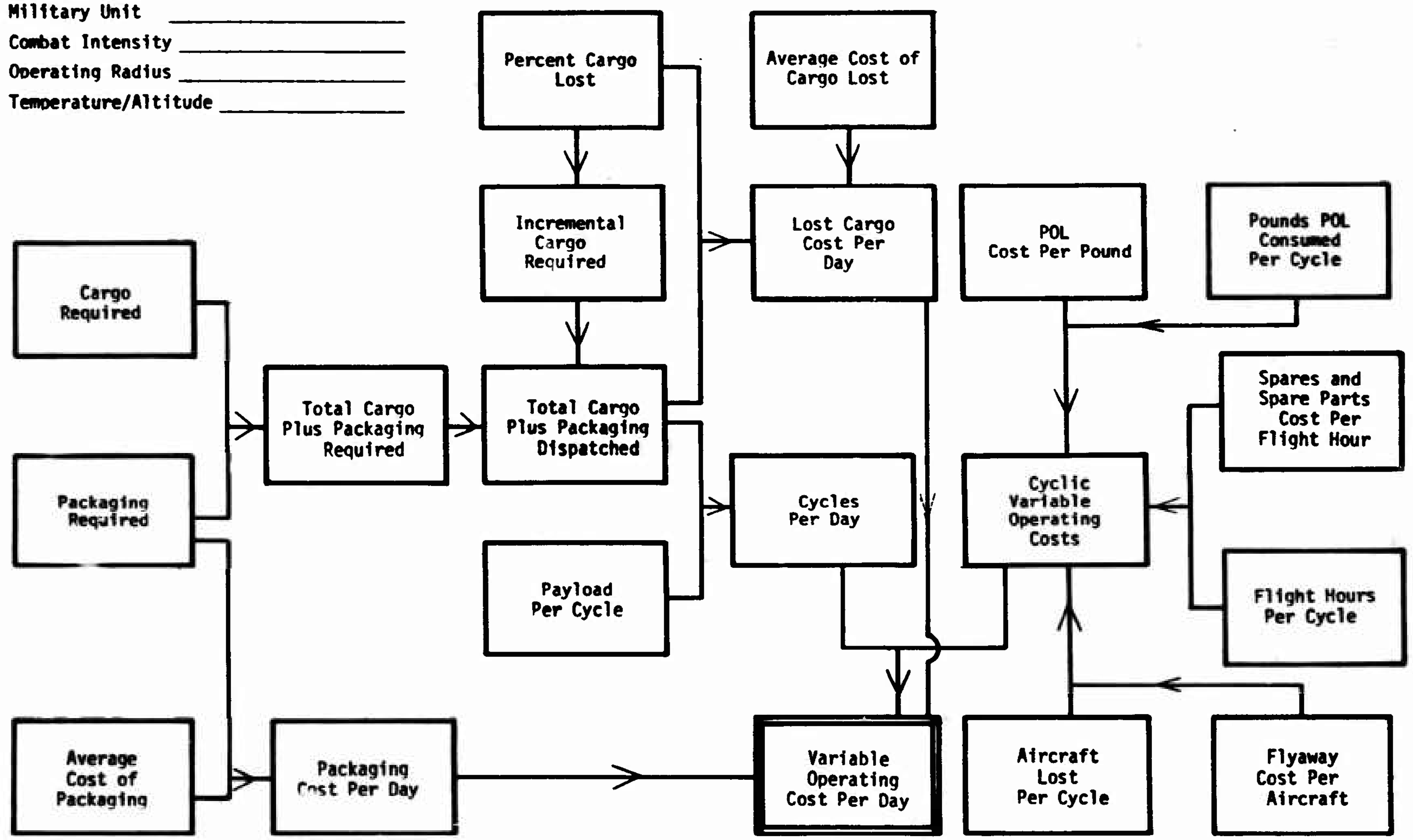


Figure 124. (U) Resupply Operation Variable Operating Cost Per Day.

5. Operating radius (basic variable).

6. Temperature/altitude case (87°F/sea level or 83°F/2000 ft).

(U) Mission-Based Inputs to Cost Calculations

The calculation sequence begins with the payload/radius curve for the appropriate operation, delivery system, temperature/altitude, thrust-to-weight ratio, and delivery mode. These payload/radius curves specify the capability of the aircraft with either a conventional or a vertical/modular cargo handling system installed, but do not account for packing and rigging since these depend on the operation and unit supported.

Three inputs to the cost calculations are based on these payload/radius curves, namely:

1. Number of cycles (round-trip) required.

2. Associated flight hours and/or cycle hours.

3. Number of aircraft required based on the appropriate utilization and/or availability limitations.

(C) Number of Cycles (U)

(U) The number of cycles for both major deployments and tactical redeployments are based on transporting the same military units of the airmobile division (TOE-67T). The determinations are founded upon Figure 111 in the "Operational Comparison" chapter, and made separately for infantry battalion, 105 mm howitzer battery, engineering platoon, and a composite of all units assumed located at the brigade base in this study. The unit locations and the composition of each is developed in Appendix I. Figure 125 shows both the appropriate XC-142A payload/radius curves for deployment operations, and the number of cycles required to transport each of the four military units using three flight profiles:

1. VTOL/VTOL - based on all vertical takeoffs and landings, and used in tactical redeployments only (T/W = 1. 10).

2. STOL/VTOL - based on having an airfield at the origin and landing vertically at the destination, and used in both major deployments and tactical redeployments (T/W = 1. 10).

3. STOL/STOL - based on having an airfield at both origin and destination, and used only in major deployments.

(U) In certain radii-ranges, the number-of-cycles curves are flat or tend to increase more slowly due to volume limitations. The manner in which some of the curves sweep upward at longer radii is deceptive. Actually, the number of cycles required would increase at an increasing rate as

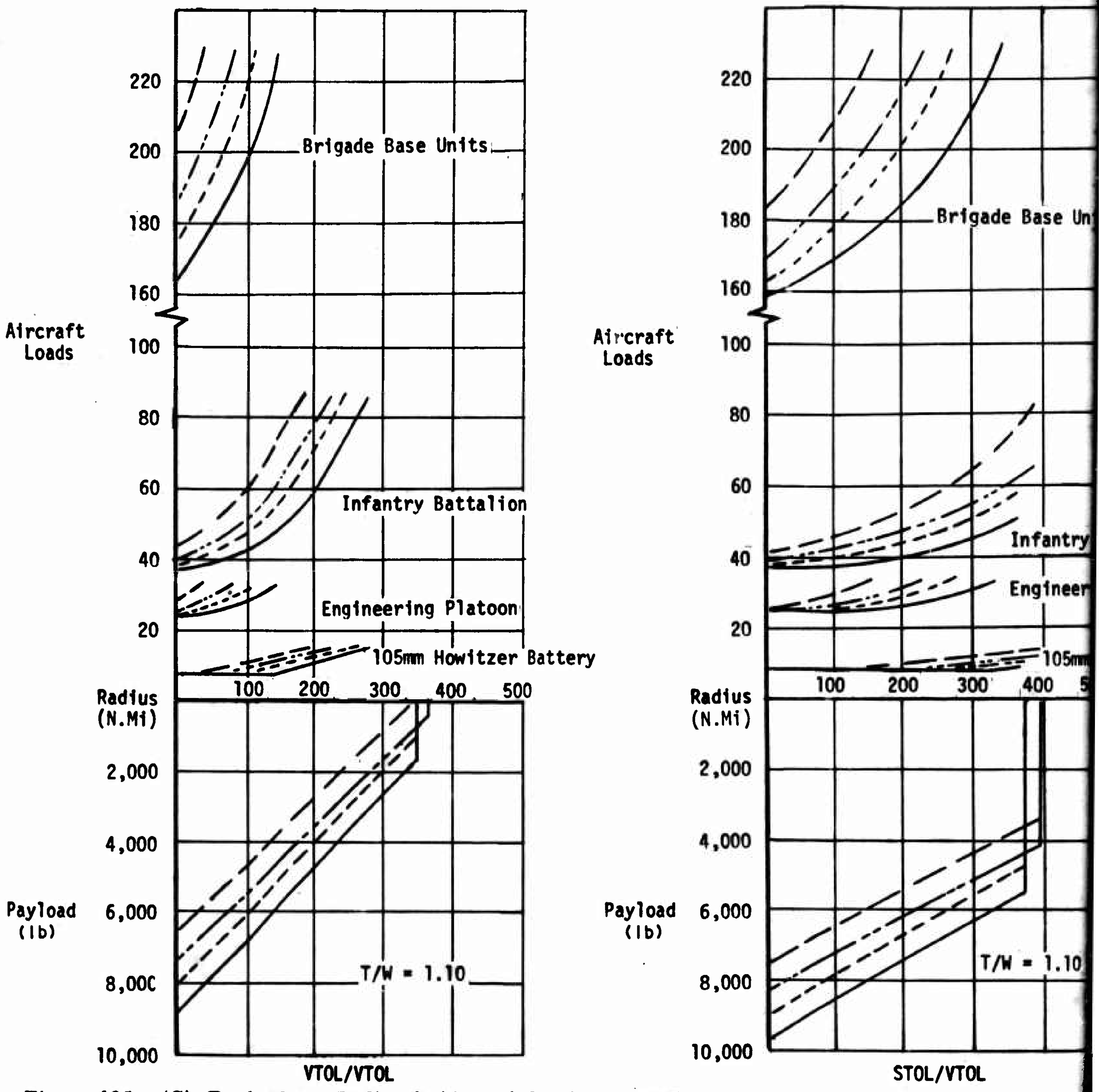
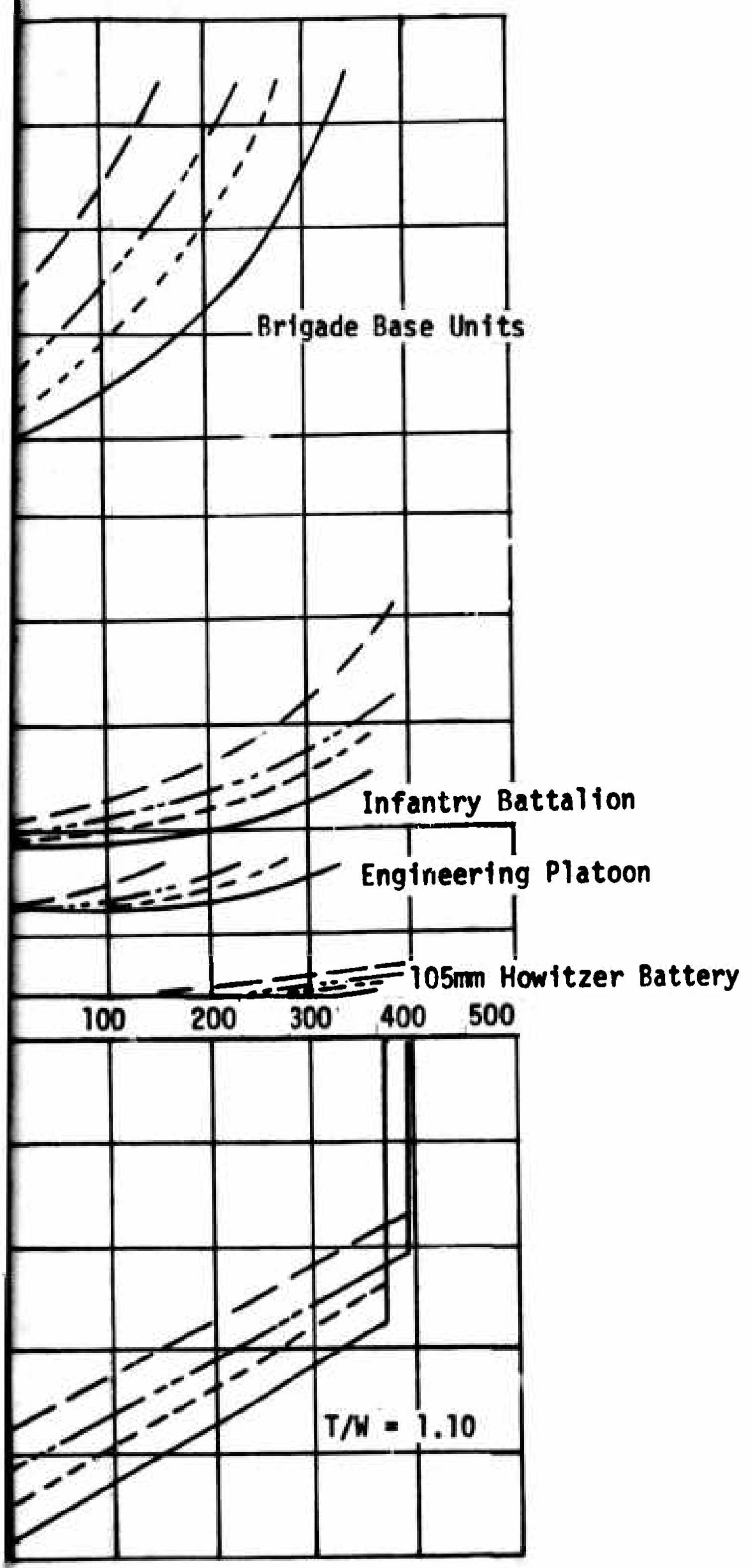
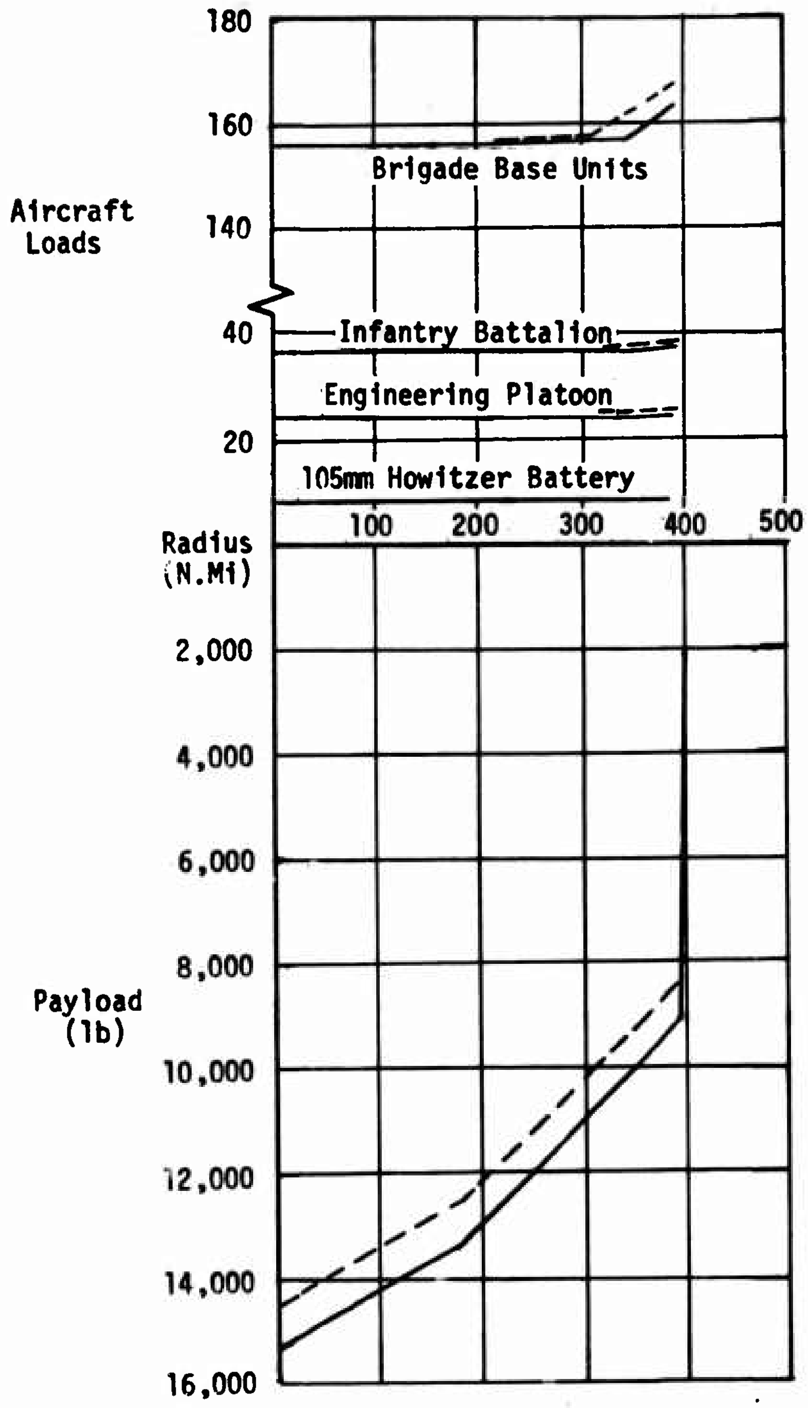


Figure 125. (C) Payload vs. Radius & Aircraft Loads vs. Radius by Flight Profile for Deployment of Brigade Base and Battalion Area Units. (U)



STOL/VTOL



STOL/STOL

————	Conventional	87°F/SL
– – – –	Vertical/Modular	87°F/SL
—— – ——	Conventional	83°F/2000 ft
—— ——	Vertical/Modular	83°F/2000 ft

2

radius increases except for the fact that volume-limited loads increase the cycles required at the lower radii where the aircraft payload is highest. The curves for the engineering platoon stop at the radius corresponding to 5800 pounds due to the large number of 3/4-ton trucks in the unit.

(U) To calculate the number of cycles required for daily resupply of the battalion areas or brigade bases, two items of basic data are required:

1. The average pallet or 500-gallon fuel drum weight.

2. The average weight of the packing, rigging, and parachutes per unit weight of cargo delivered for the appropriate cargo mix and the delivery mode employed.

(C) Table XLVI shows the net payload degradation due to packing and rigging for daily resupply by the various delivery modes, and for the battalion area and brigade-base cargo mixes. These payload degradations are based on an average 1740-pound pallet, a 3600-pound fabric fuel drum, and the packing and rigging weights discussed in the "Operational Comparison" chapter.

(U) Figures 126 and 127 give the resulting payload/radius curves, showing the actual supplies transported after the appropriate packing and rigging weight has been deleted.

(U) Two payload limitations are shown for both airdrop and hover-drop with the conventional delivery system. Airdrop payload is limited by the weight per pallet dropped and the length of the cargo compartment. The upper limit for airdrop, 7 pallets, was used in the evaluation.

(U) The limitations for the "dump-truck" type of hover-drop delivery are cited in Reference 18. Again, the upper-limit payload (6600 pounds) was used in the evaluation, even though only the lower limit (4000 pounds) had been demonstrated in the tests at El Centro, California, in April 1966. These limitations are discussed further in the "Stability and Control" and "Operational Comparison" chapters.

(U) The number of cycles required to deliver the quantities of cargo from Table XLVII to one battalion area or brigade base were calculated using equation 3 and the data from Table XLVII and Figures 108, 126, and 127.

$$\text{Cycles Required} = \frac{\text{Weight of Cargo Requested}}{\text{(Percent Cargo Lost) (Aircraft Payload Per Cycle)}} \qquad (3)$$

Note that this equation is based on recycling until the cargo delivered approaches the cargo requested, that is:

$$\lim_{n \to \infty} \left[1 + \sum_{n=1}^{\infty} X^n \right] = \frac{1}{1-X} \text{ for } X < 1 \qquad (4)$$

where X is the percent of the cargo lost per cycle, and n is the number

TABLE XLVI (C)
DELIVERED SUPPLIES AS A PERCENTAGE OF AVAILABLE PAYLOAD (U)

Delivery Mode	Resupply Cargo	Ratio Supplies to Supplies, Packing, & Rigging	
		Conventional	Vertical/Modular
General Factors			
STOL-land & VTOL-land	500-Gal Fuel Drum	1.000	1.000
	40 x 48-Inch Pallet	0.946	0.946
Airdrop	500-Gal Fuel Drum	0.913	0.924
	40 x 48-Inch Pallet	0.837	0.854
Hover-drop	500-Gal Fuel Drum	0.976	0.980
	40 x 48-Inch Pallet	0.904	0.926
Brigade Base Factors[1]			
STOL-land	70% Fuel By Wt	0.985	0.985
VTOL-land	70% Fuel By Wt	0.985	0.985
Battalion Area Factors[1]			
VTOL-land	94% Pallets By Wt	0.946	0.946
Hover-drop	94% Pallets By Wt	0.904	0.926
Airdrop	94% Pallets By Wt	0.837	0.854

[1]Normal combat intensity

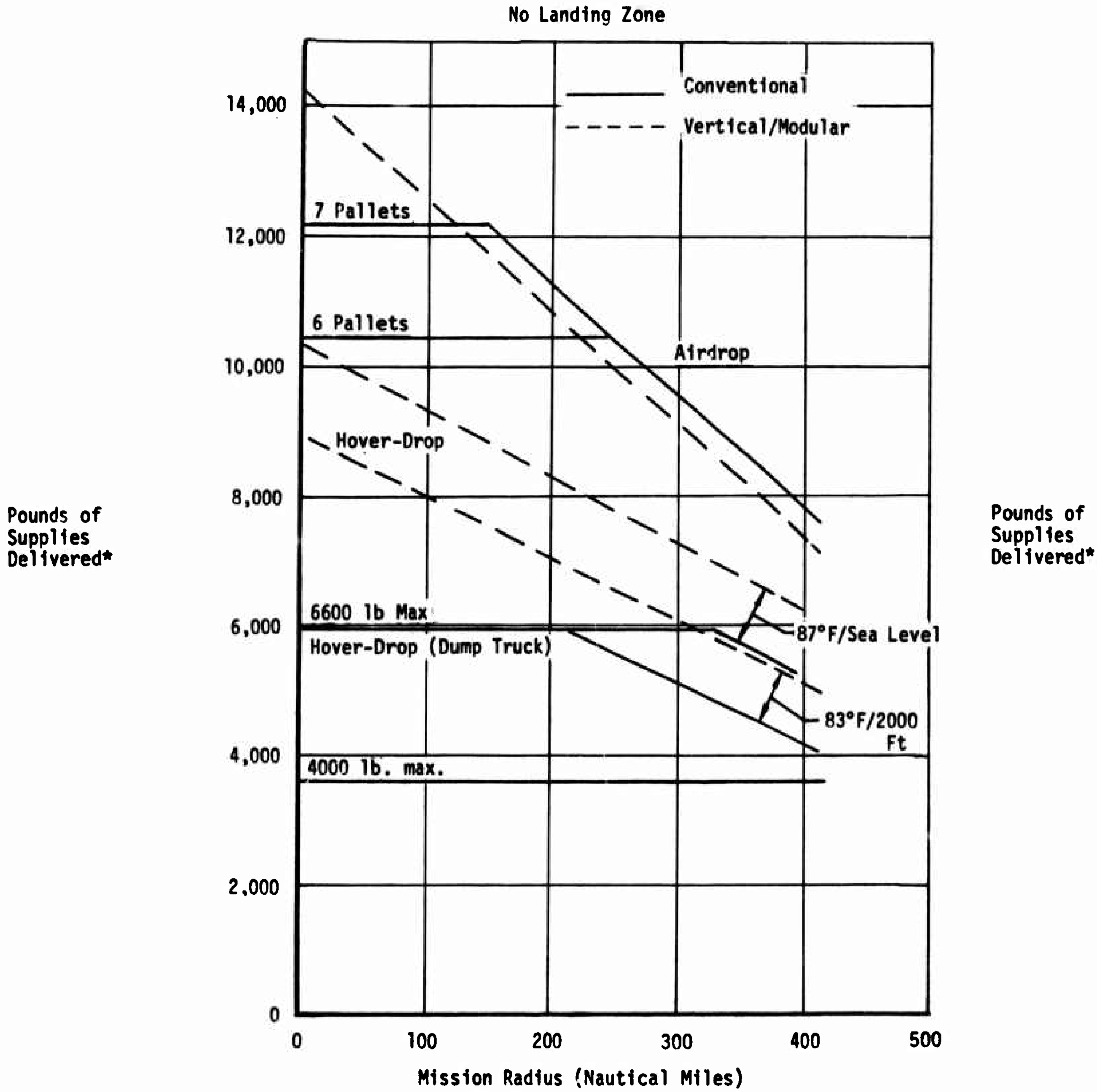
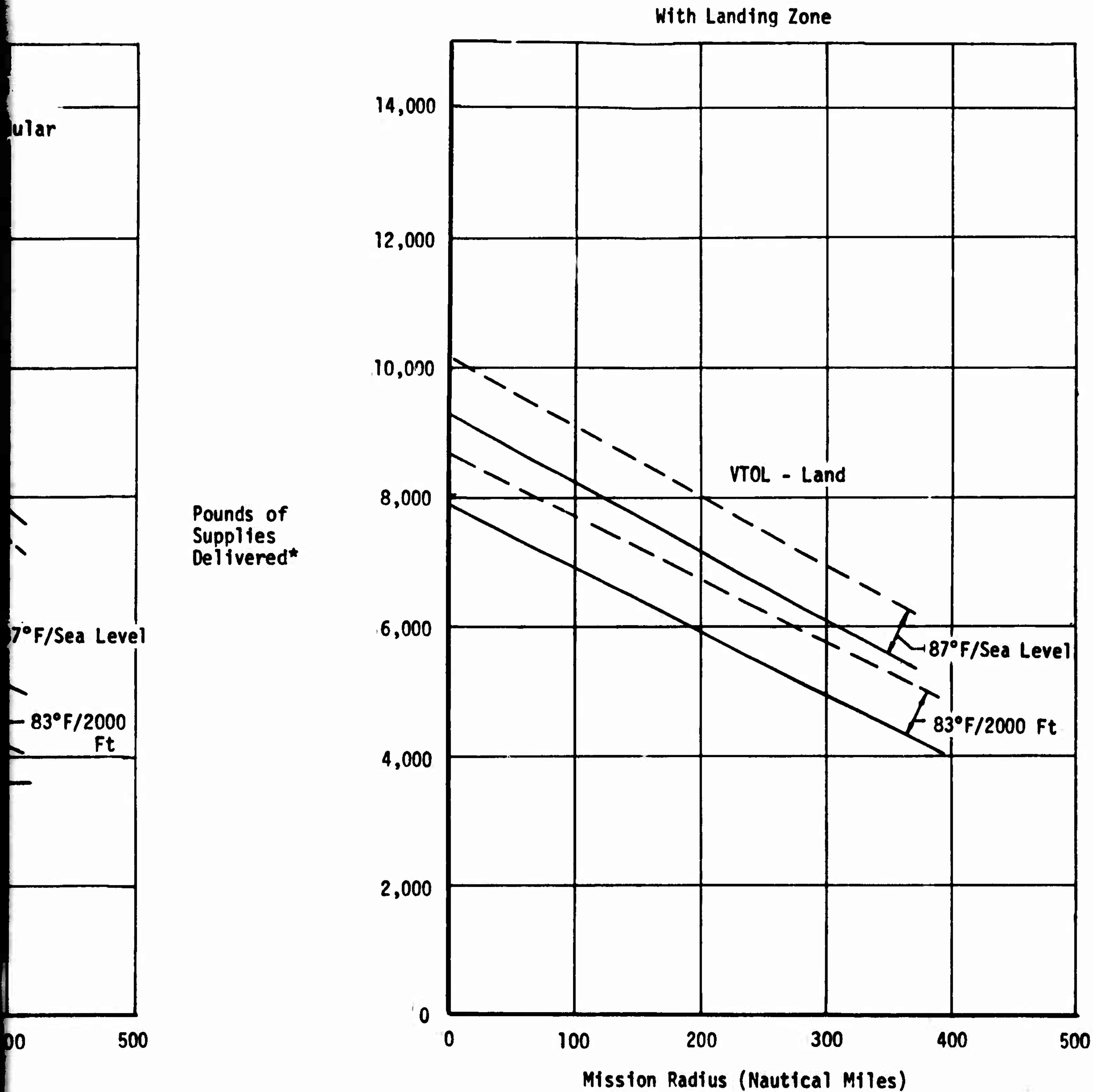
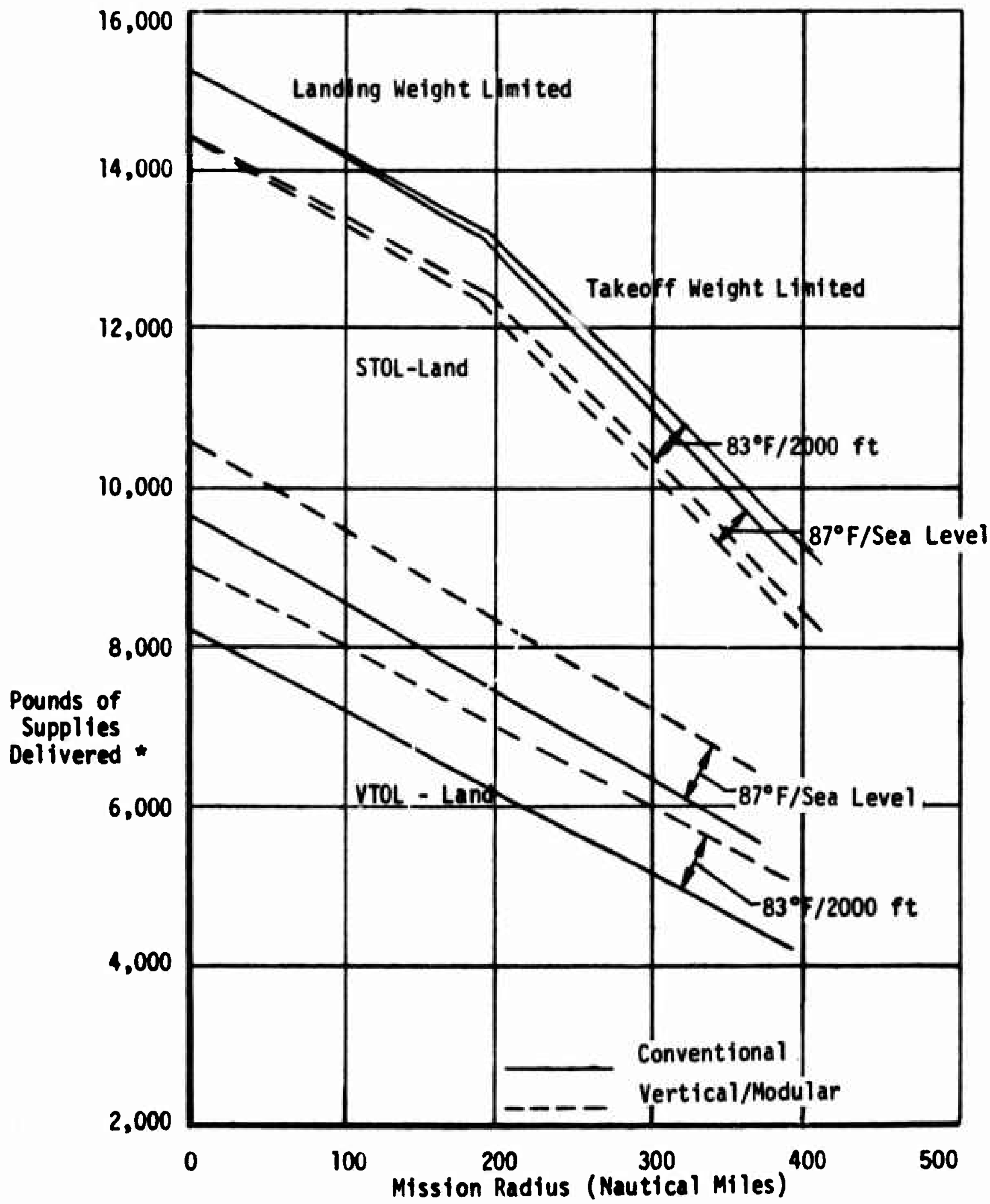


Figure 126. (C) Delivered Payload versus Mission Radius for Battalion Area Resupply by Delivery Mode. (U)



* Aircraft Payload Less the Weight of Packing and Rigging

2



* Aircraft Payload Less the Weight of Packing and Rigging.

Figure 127. (C) Delivered Payload vs. Mission Radius for Brigade Area Resupply. (U)

of sequential cycles flown to replace lost cargo. For example, with a 10-percent loss rate per cycle, 99 percent of the supplies requested would reach the user after 2 sequential cycles; 99.9 percent, after 3 cycles.

(C) The appropriate aircraft payload includes packing, rigging, and parachutes. Cargo was assumed to be lost in two delivery modes:

1. Conventional hover-drop: 2-percent loss due to impact damage.

2. Conventional and vertical/modular airdrop:

   - 5-percent loss due to parachute failures and impact damage at 87°F/sea level.
   - approximately 15-percent loss, varying with the number of pallets dropped, using Figure 108 and a 450-yard drop zone at 83°F/2000 ft.

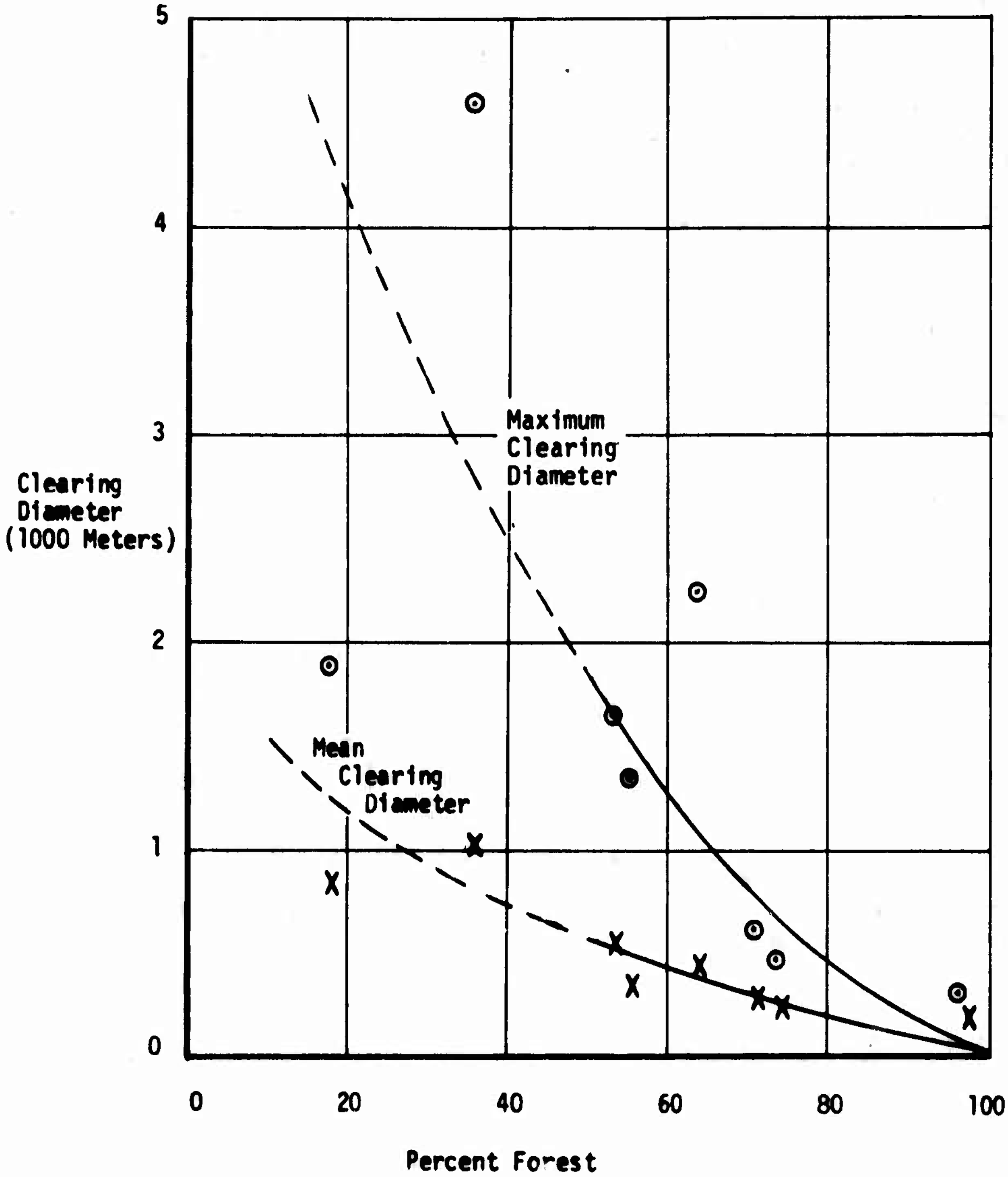
The derivation of these losses is discussed in the "Operational Comparison" chapter. The 450-yard drop zone size is an illustrative value for a heavily forested area, and is essentially a subjective choice in light of the gross trends sketched in Figure 128.

TABLE XLVII (C)
RESUPPLY CARGO QUANTITY BY CLASS SUPPLIES (U)

Class	Battalion Area [1] Normal (lb per day)	Battalion Area [1] Maximum (lb per day)	Brigade Base [1] Normal (lb per day)	Brigade Base [1] Maximum (lb per day)
I	5,350	5,350	8,000	8,000
II & IV	5,102	7,648	6,880	10,320
III	3,600	3,720	20,400	30,600
IIIA	-	-	183,700	370,800
III & IIIA (O&L)	75	122	4,230	8,240
V	45,559[2]	111,344[2]	6,764	11,064
VA	-	-	59,654	121,208
Total	59,686	128,184	289,628	560,232

1 Excluding weight of pallets and rigging; including packaging normally holding supplies in a given geometric shape, e.g., ammunition boxes and 500-gallon fuel drums.

2 24,000-lb 105 mm howitzer at normal combat intensity, 64,800 lb at maximum; 9,360-lb 81 mm mortar at normal, 20,280 lb at maximum.



Source: Ref 97, Pg. E-67

Figure 128. (U) Mean and Maximum Clearing Diameter Versus Percent of Area Which is Forest.

(C) Total Flight Hours (U)

The total number of flight hours is determined using equation 5:

$$\text{Total Flight Hours} = \text{Number Cycles} \times \text{Flight Hours Per Cycle} \qquad (5)$$

The flight hours per cycle shown in Figures 129 and 130 are assumed to vary with the radius and delivery mode, but not with the temperature/ altitude or delivery system.

(C) Total Cycle Hours (U)

The total number of cycle hours is determined using equation 6:

$$\text{Total Cycle Hours} = \text{Number Cycles} \times \text{Cycle Hours Per Cycle} \qquad (6)$$

where the cycle hours are the sum of ground hours and flight hours. The ground hours per cycle are given for each delivery mode in Table XXXIII in the "Operational Comparison" chapter.

(C) Number of Aircraft Required (Utilization) (U)

The number of complement (inventory) aircraft required is calculated based on a utilization of 4 hours per day per complement aircraft for daily resupply at normal combat intensity, using equation 7.

$$\text{Number Aircraft Required} = \frac{\text{Total Flight Hours}}{\text{4 Hours Per Day}} \qquad (7)$$

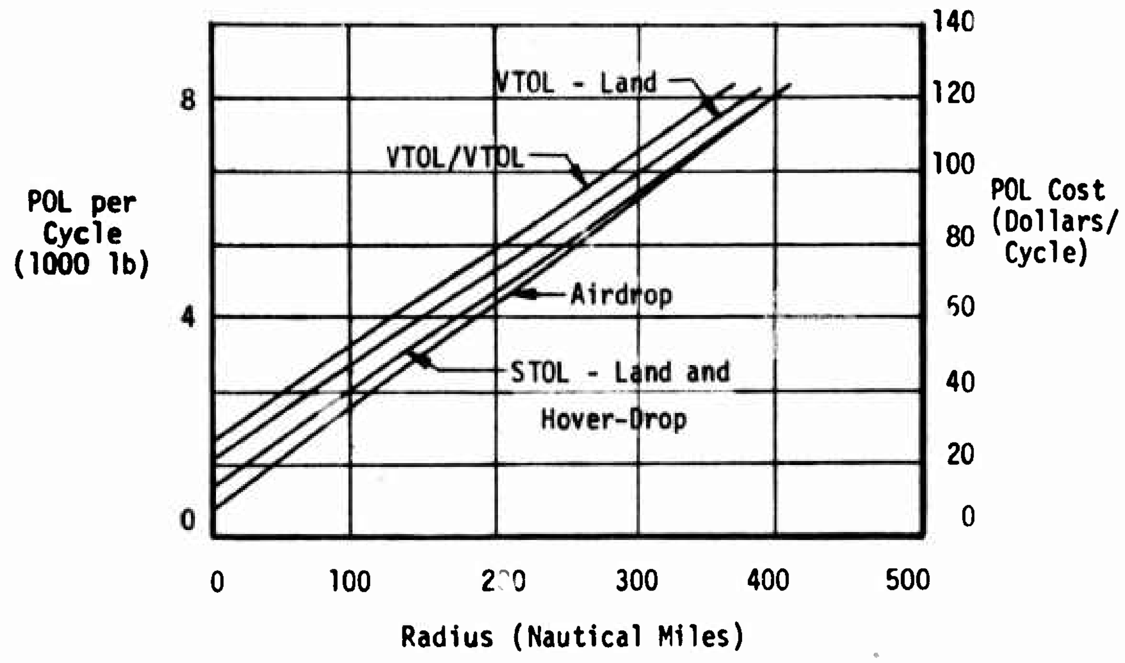
This calculation is independent of aircraft availability so long as the total cycle hours per day (flight hours plus ground hours) per available aircraft do not exceed the 12-hour operating day. For example, with one ground hour per flight hour (8 cycle hours per 4 flight hours) and 67 percent of the complement aircraft available, the cycle hours would equal 12 per available aircraft, just meeting the criteria. There is no danger of exceeding the criteria at the radii of interest in this study with availabilities at least as low as 50 percent.

(C) Number of Aircraft Required (Operating Day) (U)

(C) For daily resupply at maximum combat intensity, and all deployment missions, the number of aircraft required was calculated based on a 12-hour operating day, using equation 8:

$$\text{Number Aircraft Required} = \frac{\text{Total Cycle Hours}}{\text{12 Hours Per Day}} \qquad (8)$$

It is important to note that these are available aircraft, not complement aircraft, the number of available aircraft being the product of the availability and the number of complement aircraft.



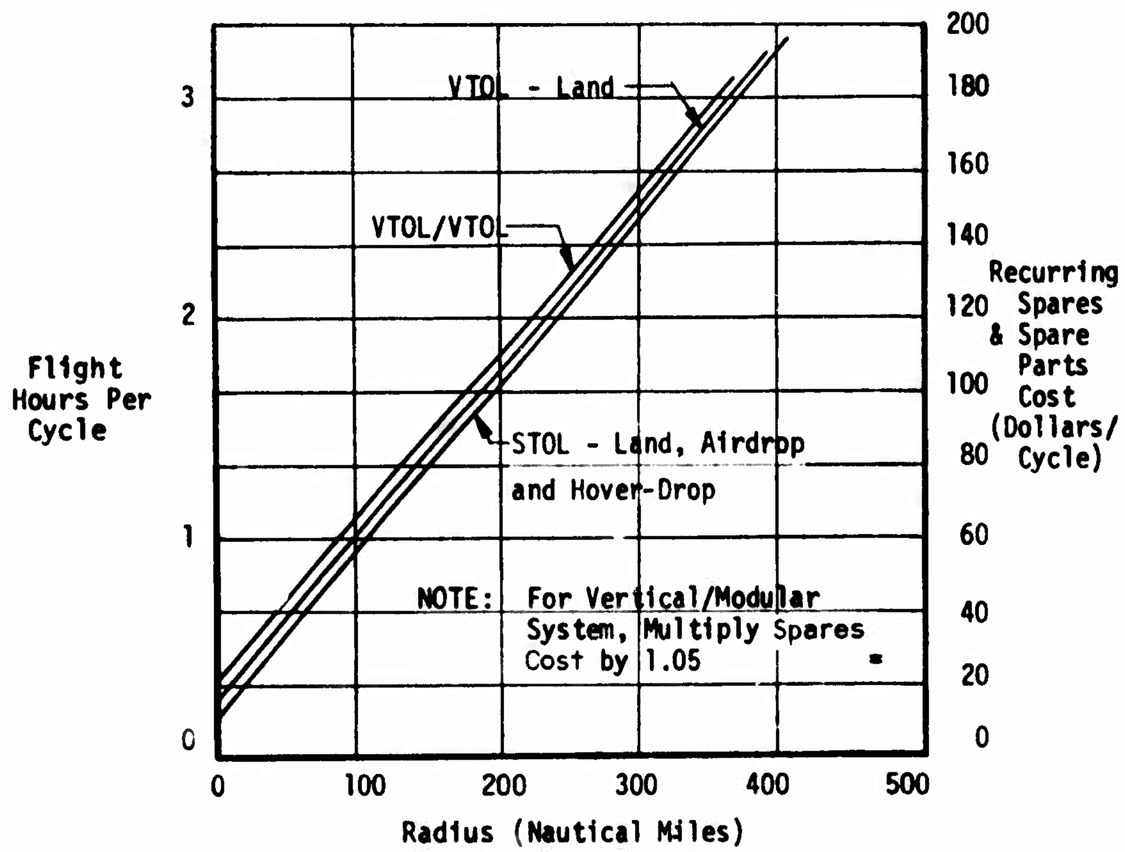
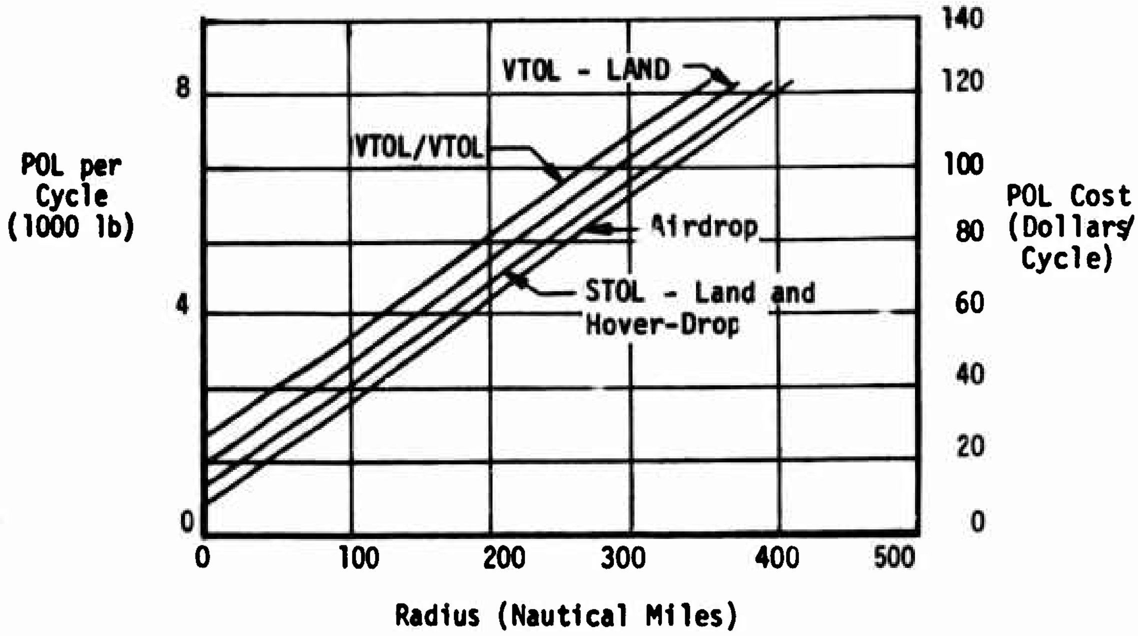


Figure 129. (C) Flight Hours, POL Cost & Recurring Spares Cost Versus Radius; Lowland Region. (U)



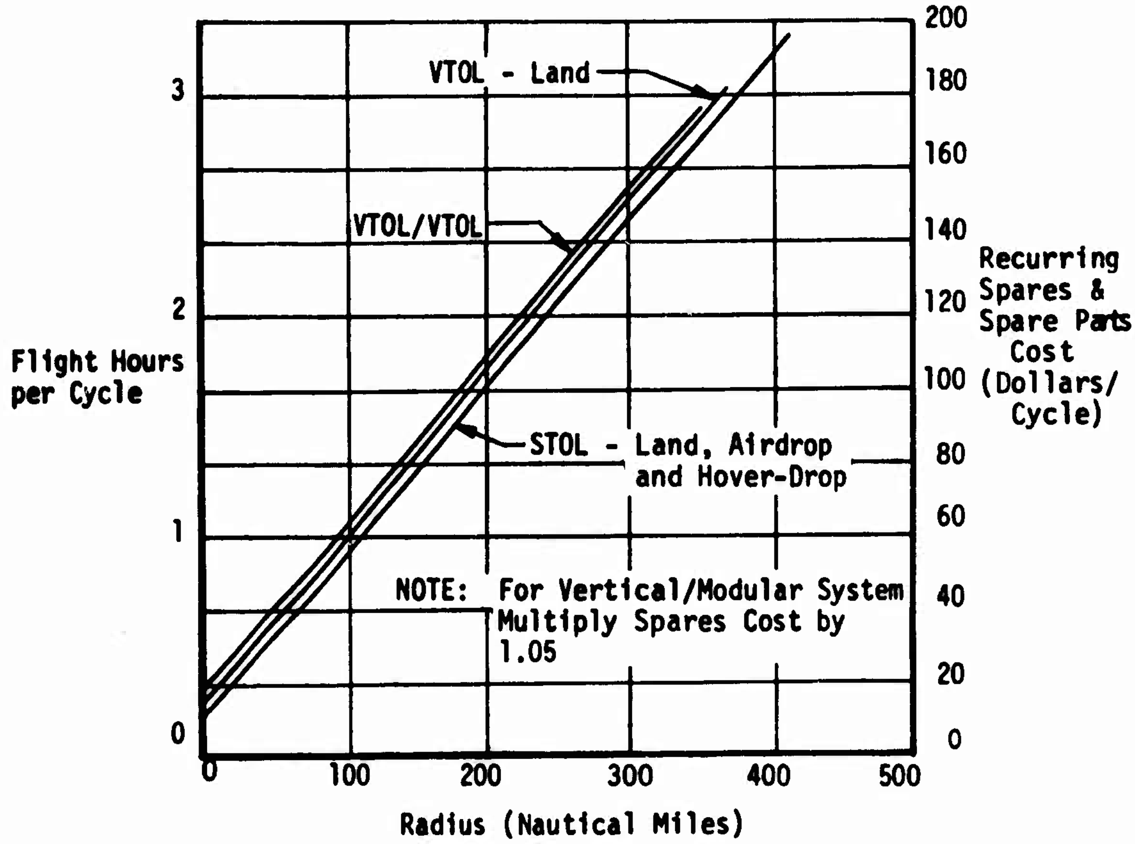


Figure 130. (C) Flight Hours, POL Cost and Recurring Spares Cost Versus Radius; Highland Region. (U)

(C) This criterion is of greater interest for resupply at maximum combat intensity and deployment missions because the question in maximum resupply is whether enough aircraft will be available to meet this ultimate mission at a high utilization, and the objective in deployment missions is to complete the movement in a given number of lifts or in a given time period. In contrast, the primary mission of the delivery systems discussed in this study is to provide sustained "normal" resupply to battalion area and brigade base units, in which event the number of aircraft based on an average utilization per complement aircraft per month is more appropriate.

(U) COST ELEMENTS

Variable operating cost calculations terminate with the determination of the following parameters as a function of the fundamental variable, radius:

1. Fuel cost.
2. Recurring spares cost.
3. Cost of aircraft lost due to accidents and enemy fire.
4. Cost of cargo lost (including the associated packing and rigging) due to parachute failures, impact damage, or delivery accuracy where appropriate.
5. Cost of packing, rigging, and parachutes excluding that associated with lost cargo, i. e., that required if no cargo is lost.

(U) Fuel Cost

The total fuel cost is calculated by equation 9, where the fuel cost per cycle may be determined from Figures 129 and 130.

Total Fuel Cost = Fuel Cost Per Cycle x Number Cycles (9)

While fuel cost per cycle approaches fuel cost per flight hour at longer radii, errors as great as 100 percent in total fuel cost can result from using fuel cost per flight hour, due to the block of fuel consumed in takeoff and landing. Fuel cost per cycle avoids these errors at short radius.

(U) Recurring Spares Cost

Figure 129 gives the recurring spares cost per cycle versus radius, but it is more expeditious to calculate this parameter using equation 10.

Total Spares Cost = Spares Cost Per Flight Hour x Total Flight Hours (10)

The spares costs per flight hour are \$60 and \$63 for the conventional and vertical/modular delivery systems, respectively.

(U) Cost of Lost Aircraft

Equation 11 was used to calculate the cost of lost aircraft, based on the loss rates given in Table XLV in the "Wartime Evaluation Mission" chapter.

$$\text{Cost Lost Aircraft} = \text{Flyaway Cost} \times \text{Loss Rate Per Cycle} \times \text{Cycles} \tag{11}$$

Table XLVIII gives the product of the first two terms of equation 11, the dollar cost of lost aircraft per single-aircraft cycle. No penalty was assessed for training replacements for crew casualties.

(U) Cost of Lost Cargo

Based on the cargo loss rates previously discussed and the costs per ton of cargo lost presented in Table XLIV, the total cost of lost cargo was determined using equation 12.

$$\text{Cost of Lost Cargo} = (\text{Cost Per Ton Cargo Lost}) \times \left(\frac{\%\text{Cargo Lost Per Cycle}}{1 - \%\text{ Cargo Lost Per Cycle}}\right) \times \left(\begin{array}{c}\text{Tons Cargo}\\ \text{Requested}\end{array}\right) \tag{12}$$

It is important to note that the cost factors are per ton of requested cargo lost, which excludes the weight of the associated packing, rigging, and parachutes. The choice of this base facilitates calculations and promotes clarity. Once again, the necessary assumption to maintain a constant resultant effectiveness is that the aircraft are recycled until the cargo delivered approaches the cargo requested.

(U) Cost of Packing and Rigging (Excluding Lost Cargo)

The cost of packing and rigging that would be required if no cargo were lost was calculated using Table XLIII and equation 13.

$$\begin{array}{c}\text{Cost Packing}\\ \text{and Rigging}\end{array} = \begin{array}{c}\text{Cost Packing and Rigging}\\ \text{Per Ton Cargo Requested}\end{array} \times \begin{array}{c}\text{Tons Cargo}\\ \text{Requested}\end{array} \tag{13}$$

Figure 131 illustrates the relative magnitude of the costs for air-land, hover-drop, and airdrop. No recovery of packing and rigging was assumed because recovery of inexpensive items is uneconomical (pallets) and recovery of expensive items (parachutes) is improbable in light of the circumstances under which airdrop would be used with a V/STOL aircraft.

(U) TOTAL VARIABLE OPERATING COST

Total variable operating cost is the sum of the above cost elements (equation 14).

$$\begin{array}{c}\text{Total Variable}\\ \text{Operating Cost}\end{array} = \text{Cost of} \left(\begin{array}{c}\text{Lost}\\ \text{Aircraft}\end{array} + \begin{array}{c}\text{Lost}\\ \text{Cargo}\end{array} + \text{Fuel} + \begin{array}{c}\text{Recurring}\\ \text{Spares}\end{array} + \begin{array}{c}\text{Packing \&}\\ \text{Rigging}\end{array}\right) \tag{14}$$

No lost cargo or packing and rigging costs accrue on the air-land deployment missions evaluated in the study.

TABLE XLVIII (C)
COST OF LOST AIRCRAFT PER AIRCRAFT PER CYCLE (U)

Operation	Military Unit Supported	Delivery Mode Or Flight Profile	Lost Aircraft Cost Per Single-Aircraft Cycle			
			Normal Combat Intensity		Maximum Combat Intensity	
			Conventional ($/Cycle)	Vert/Mod ($/Cycle)	Conventional ($/Cycle)	Vert/Mod ($/Cycle)
Resupply	Battalion Area	Airdrop	241	251	301	314
		VTOL-land	471	491	760	793
		Hover-drop	326	340	471	491
Resupply	Brigade Base	STOL-land	241	251	301	314
		VTOL-land	241	251	301	314
Major Deployment	Battalion Area	STOL/STOL	241	251	-	-
		STOL/VTOL	1630	1700	-	-
Tactical Redeployment	Battalion Area	STOL/VTOL	1690	1760	-	-
		VTOL/VTOL	1690	1760	-	-
Major Deployment	Brigade Base	STOL/STOL	241	251	-	-
		STOL/VTOL	241	251	-	-
Tactical Redeployment	Brigade Base	STOL/VTOL	301	314	-	-
		VTOL/VTOL	301	314	-	-

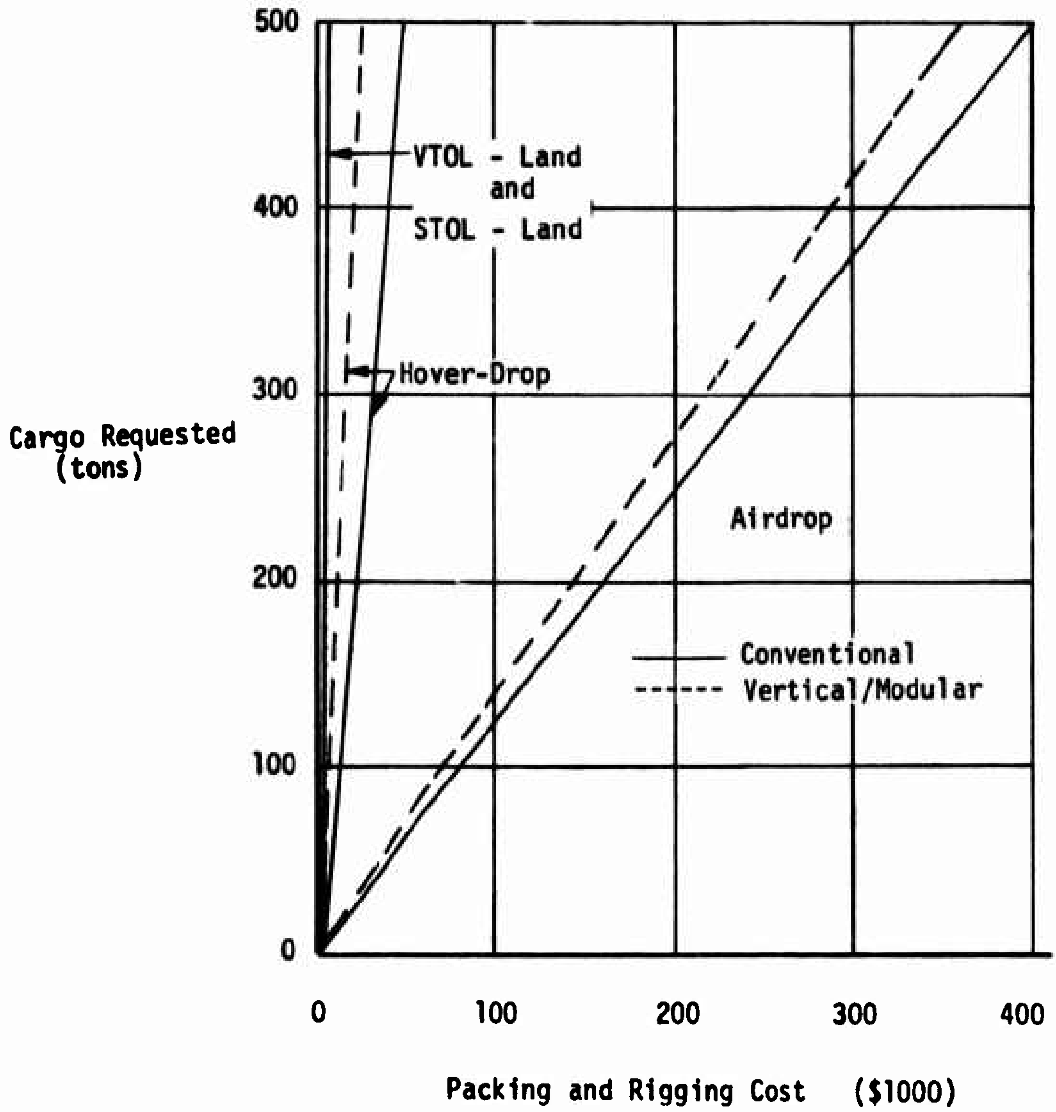


Figure 131. (C) Packing and Rigging Costs as a Function of Cargo Quantity Requested by Delivery Mode. (U)

(C) ANALYSIS OF RESULTS (U)

(U) The primary results of the evaluation, variable operating costs for the resupply and deployment missions defined in the "Evaluation Mission" chapter, are examined in this chapter. Resupply variable operating cost is the daily cost to supply the needs of two combat brigades. Deployment variable operating cost is dependent upon the combat unit moved and is independent of time constraints as long as the time constraint does not force the procurement of additional aircraft. All costs are shown as a function of mission radius and thereby illustrate the sensitivity to this important parameter.

(U) Several parameters are included in pairs to aid in understanding the final result. For the resupply mission, these include:

1. Normal and maximum combat intensity.
2. Two representative temperature/altitude cases.
3. Delivery to the brigade base area, having a landing zone or an airfield, and to the battalion area, either with or without a landing zone, but never having an airfield.

For the deployment mission,these include:

1. Two representative temperature/altitude cases.
2. Two types of deployment, major and tactical, with the differences being the aircraft vulnerability and the mission radius.
3. Several different combat units, to illustrate the sensitivity of the result to the relative quantity of men and vehicles in a unit.

Resupply and deployment variable operating costs are discussed separately.

(C) DAILY RESUPPLY VARIABLE OPERATING COST (U)

(C) Daily resupply variable operating cost was determined for the four delivery modes as a function of mission radius. The results of the evaluation are shown in Figure 132 for 87°F/2000 ft. The elements which make up the total daily variable operating cost are shown in Figure 133 covering selected representative cases. The minimum cost delivery modes based on airfield and landing zone availability are shown in Figure 134. The discussion of the daily resupply results will compare the two delivery systems for each delivery mode and will then establish the least-cost delivery mode based on three possible delivery area landing conditions.

(U) STOL-Land Delivery

The STOL-land delivery mode is used in resupplying the brigade base. Examination of the curves for the brigade base in Figure 132 indicates that the conventional delivery system is always the least costly delivery system

in this delivery mode. This is because the conventional cargo handling system is some 789 pounds lighter than the vertical/modular system, and in the STOL-land delivery mode this difference is directly subtracted from the aircraft payload

(C) VTOL-Land Delivery (U)

(C) The VTOL-land delivery mode is used in the brigade base area when an airfield is not available, and in the battalion area when a landing zone is available. The delivery site conditions are the same with the exception of the aircraft vulnerability assumed. The cost per cycle for lost aircraft is 230 and 240 dollars more in the battalion area than in the brigade area for the conventional and vertical/modular systems, respectively.

(U) The vertical/modular cargo handling system is always less costly than the conventional cargo handling system in this delivery mode. The reason for this is that the vertical/modular cargo handling system permits safe operation of the aircraft at a thrust-to-weight (T/W) ratio at least as low as 1.05. The unique capability to rapidly change aircraft gross weight while airborne is the reason for this.

(U) With the conventional cargo handling system installed in the aircraft the emergency procedure if an engine is lost is to immediately increase power on the remaining engines which, because of the propeller cross shafting, will keep the T/W ratio approximately 1.0 (see Aerodynamic Performance chapter).

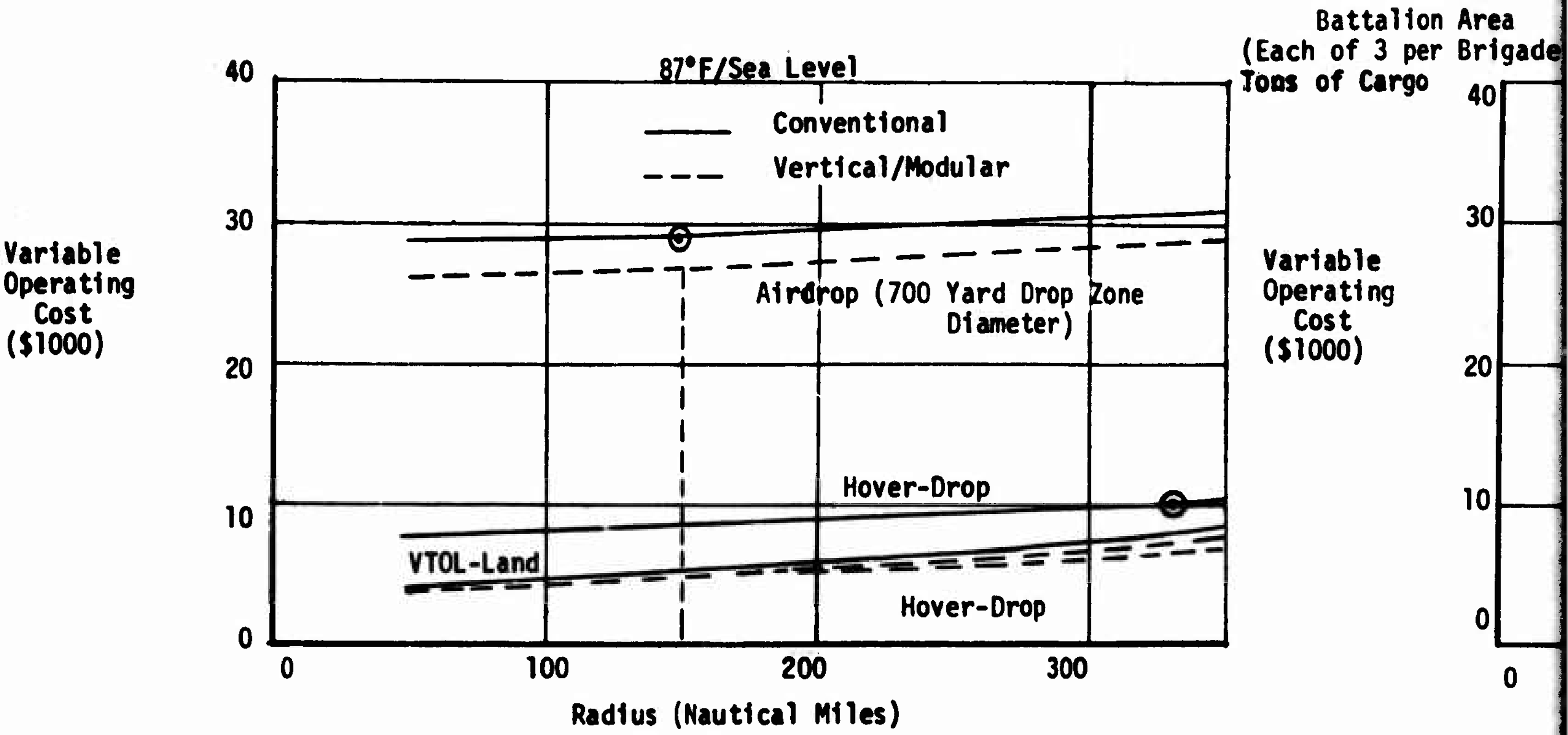
(U) With the vertical/modular cargo handling system installed in the aircraft, the approach to within approximately 20 feet of the ground is made with the bottom doors open. If an engine is lost, power on the remaining engines is increased to keep the thrust as high as possible, and cargo is jettisoned, thus decreasing the aircraft gross weight and increasing the ratio of thrust to weight. Naturally, this is possible only when the cargo being transported can be dropped through the bottom openings.

(C) The second point of interest is the difference in variable operating cost between the 87°F/sea level case and the 83°F/2000 ft case. In the VTOL flight mode, the higher altitude case is more costly. Cycles must increase to offset lower aircraft payload because reduced air density degrades engine efficiency.

(C) Hover-Drop Delivery (U)

(U) The hover-drop delivery mode is used in the battalion area when a landing zone is not available. The vertical/modular cargo handling system is less costly than the conventional cargo handling system in this delivery mode. There are four reasons for this: T/W ratio, stability and control limits, cargo damage, and weight of rigging.

(U) The T/W ratio change, previously discussed, contributes heavily to the cost differential.



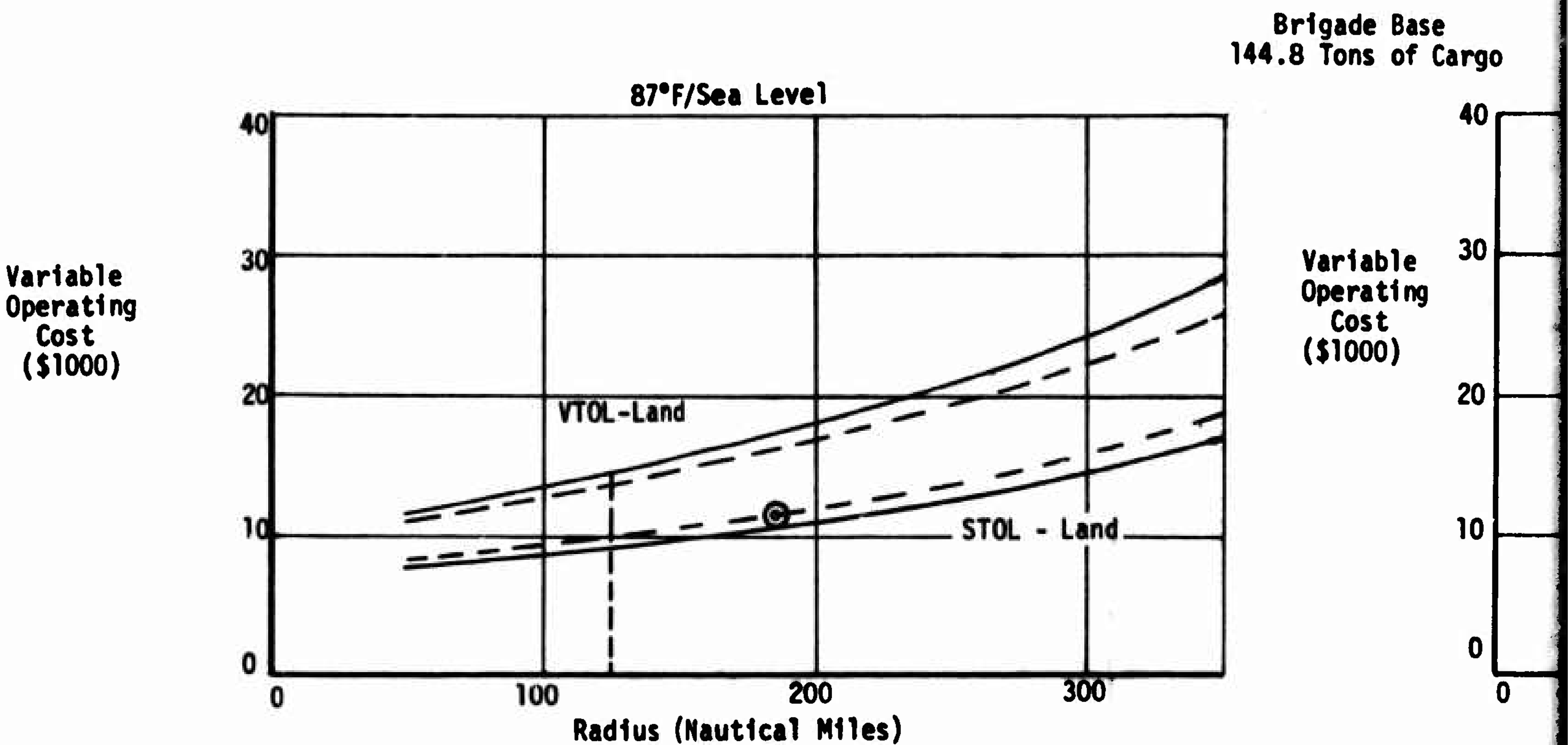
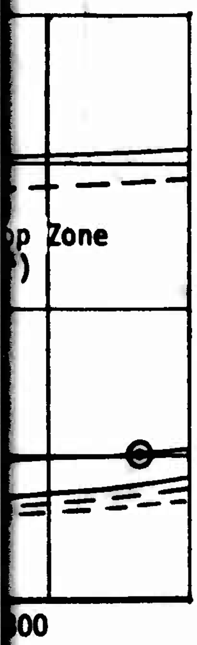
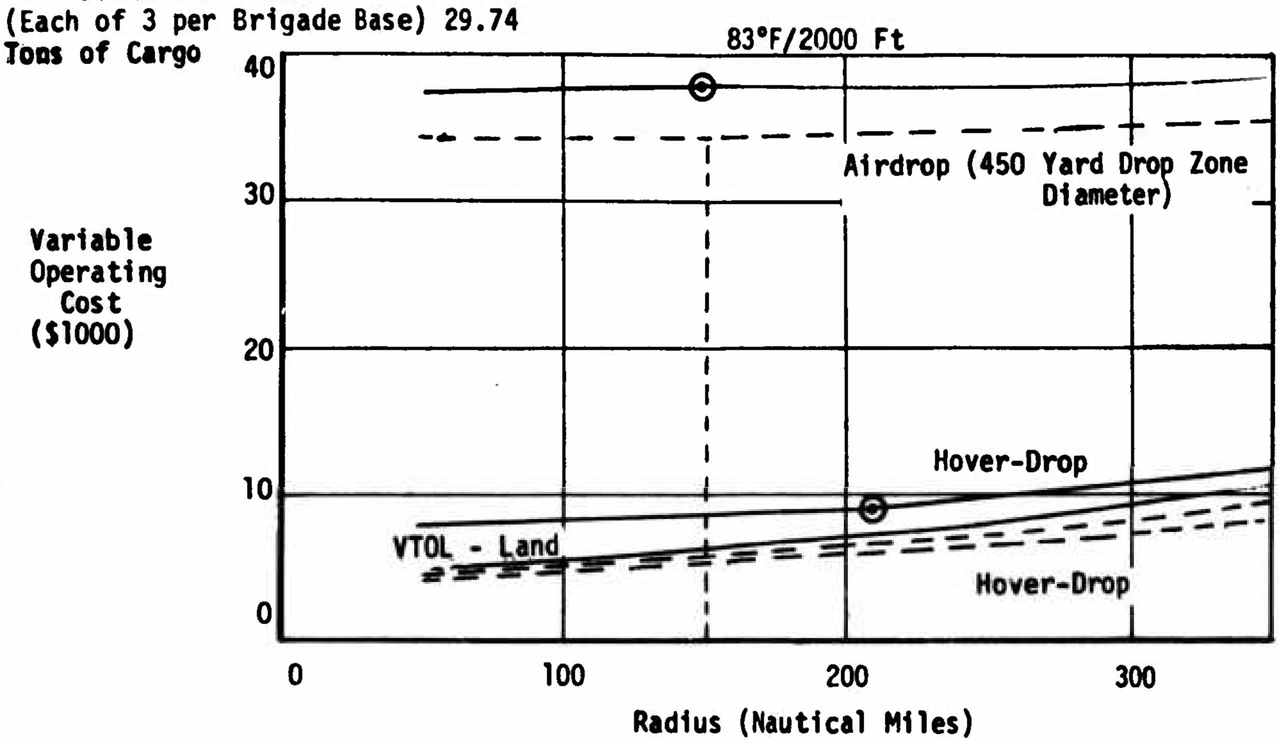


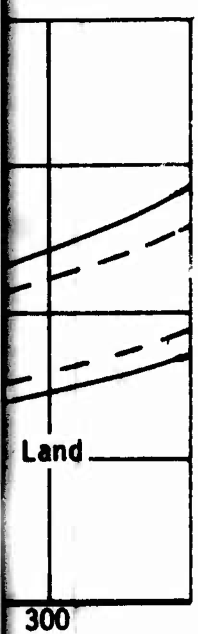
Figure 132. (C) Variable Operating Cost Versus Radius for Daily Resupply of Battalion Area and Brigade Base Units by Delivery Mode, Normal Combat Intensity. (U)

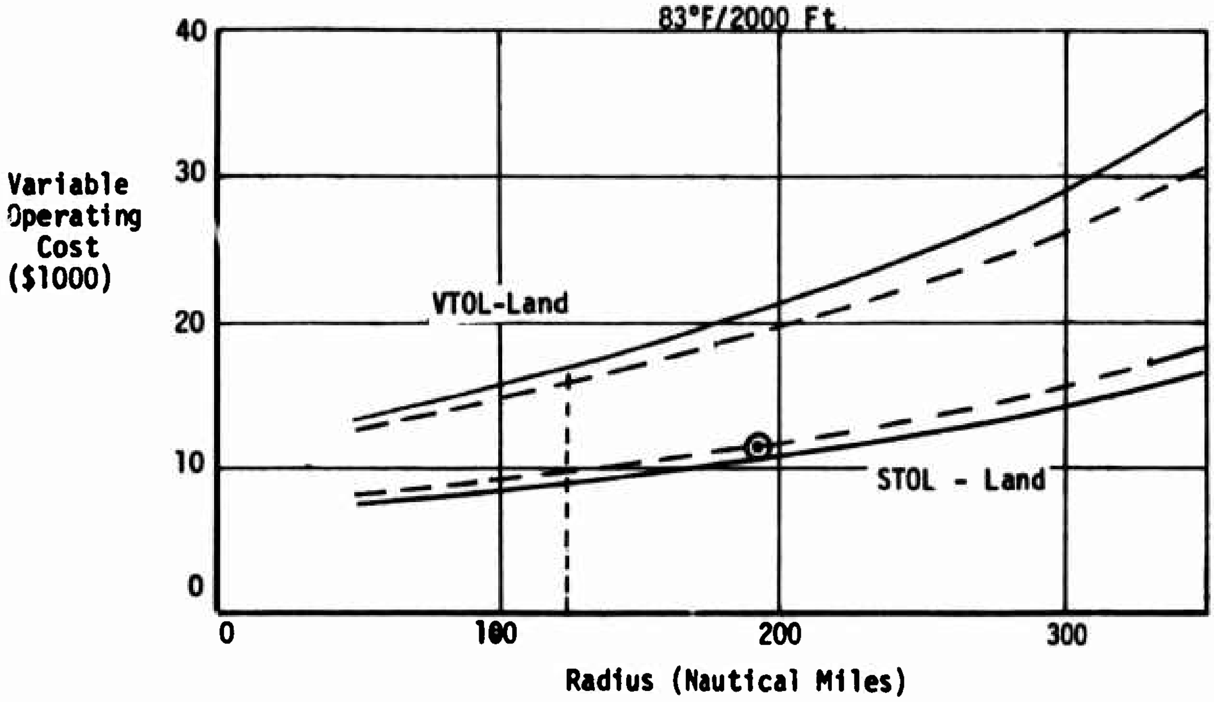
Battalion Area
(Each of 3 per Brigade Base) 29.74
Tons of Cargo





Brigade Base
144.8 Tons of Cargo





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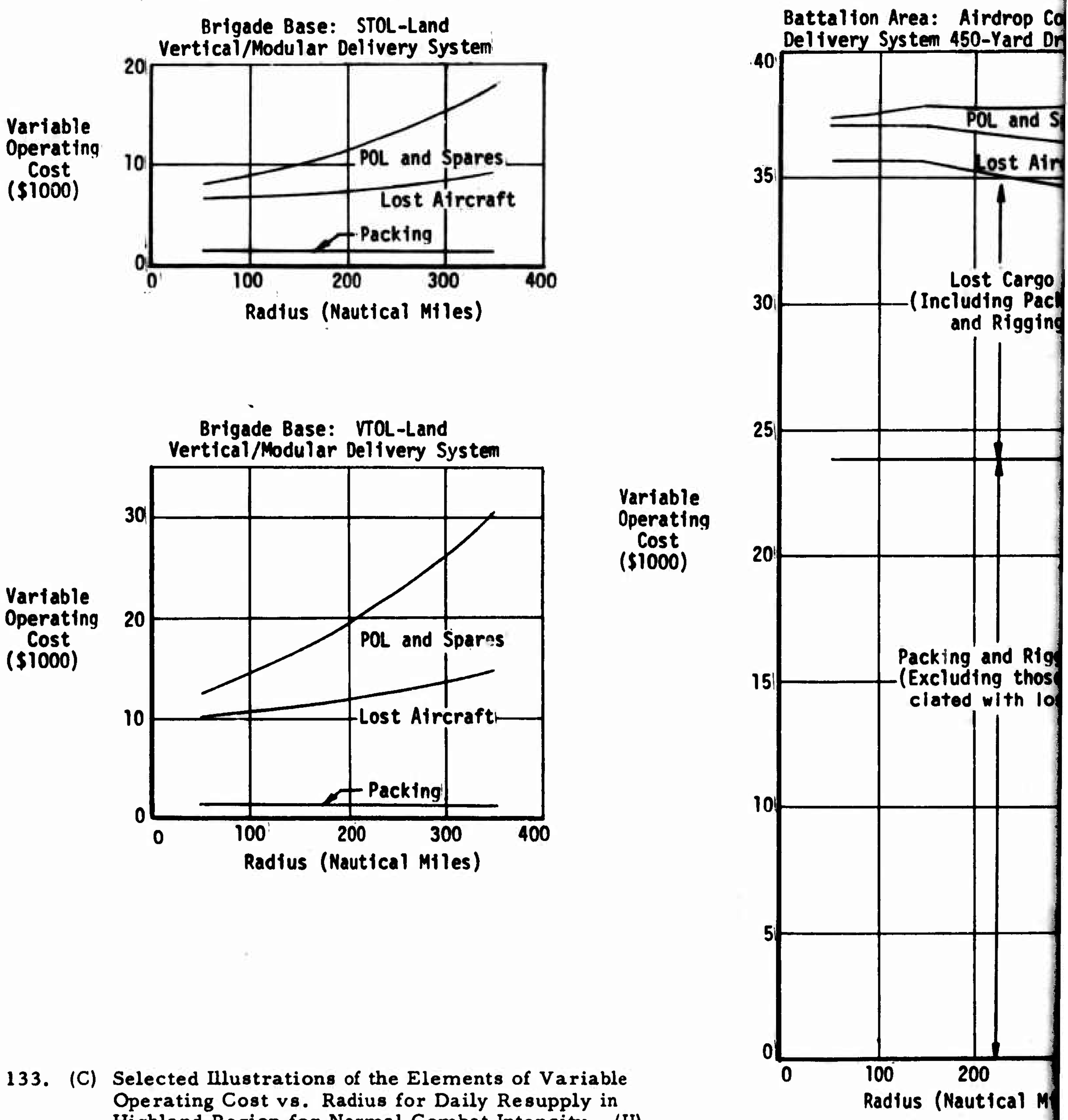

Figure 133. (C) Selected Illustrations of the Elements of Variable Operating Cost vs. Radius for Daily Resupply in Highland Region for Normal Combat Intensity. (U)

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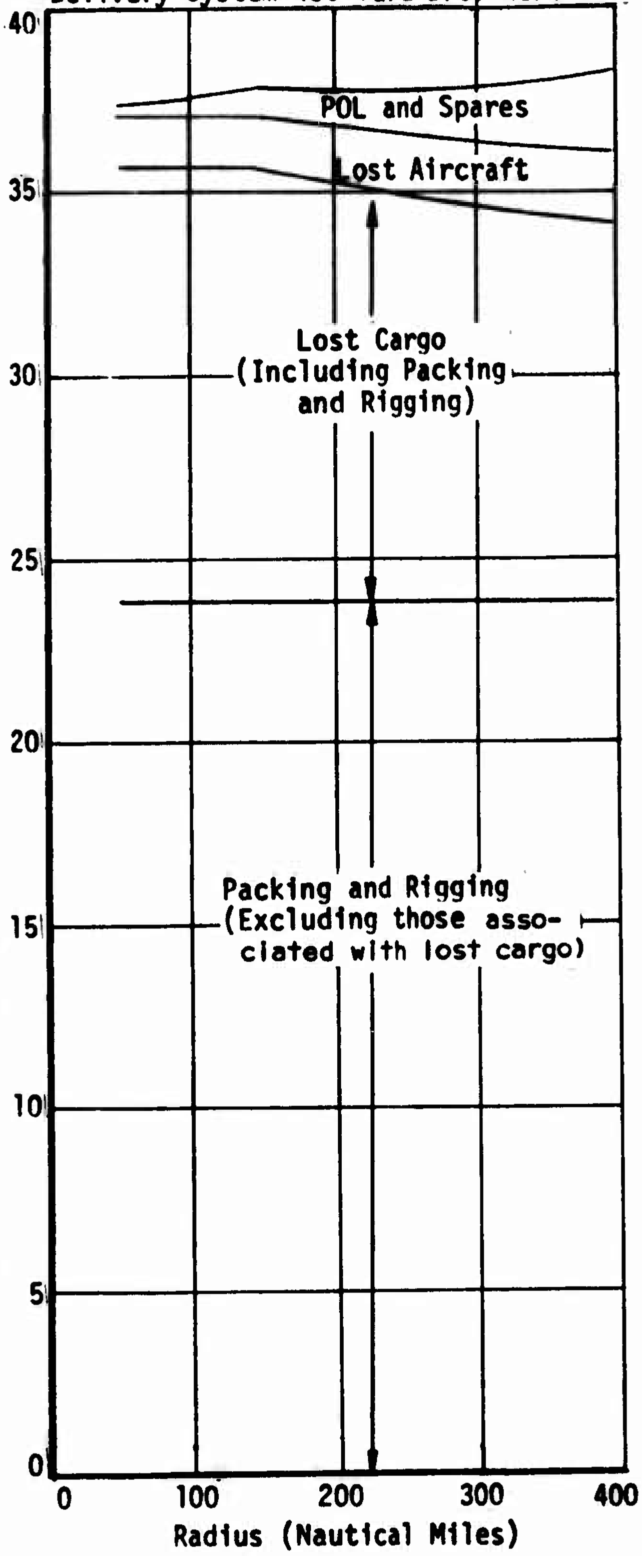
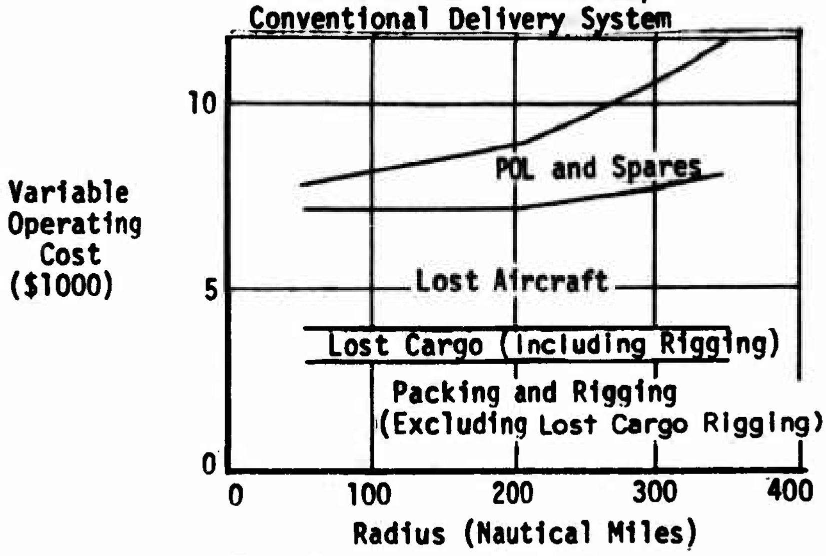
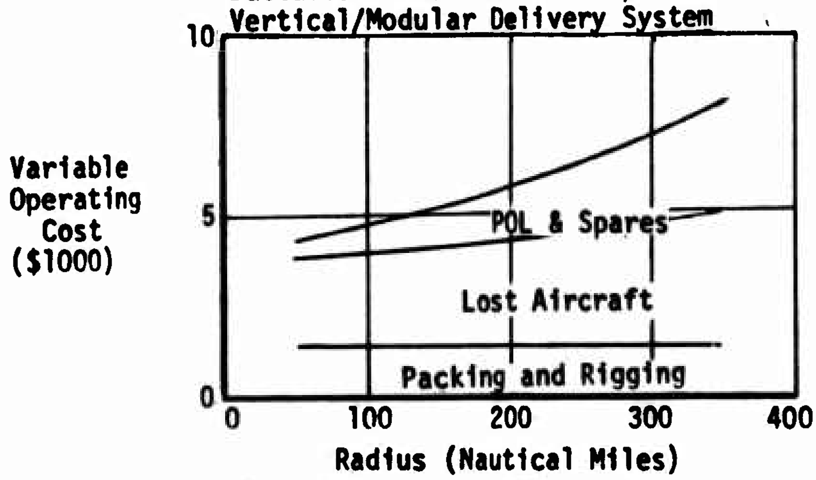
Battalion Area: Airdrop Conventional Delivery System 450-Yard Drop Zone Dia.



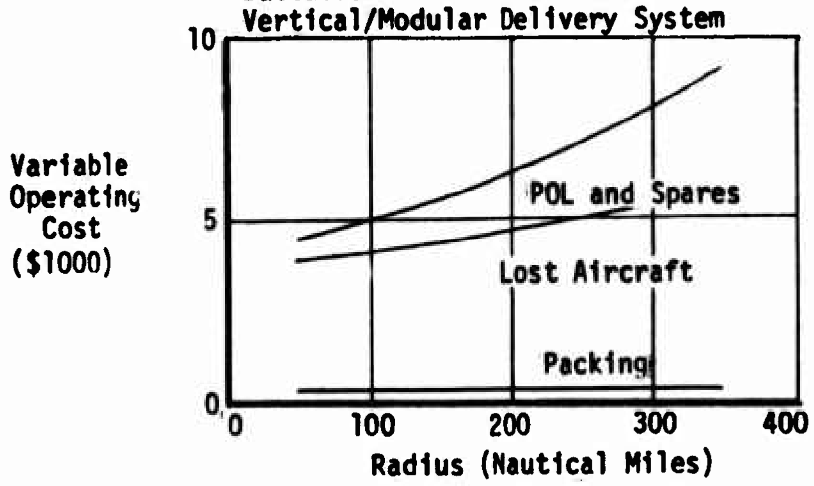
Battalion Area: Hover-Drop Conventional Delivery System



Battalion Area: Hover-Drop Vertical/Modular Delivery System



Battalion Area: VTOL-Land Vertical/Modular Delivery System



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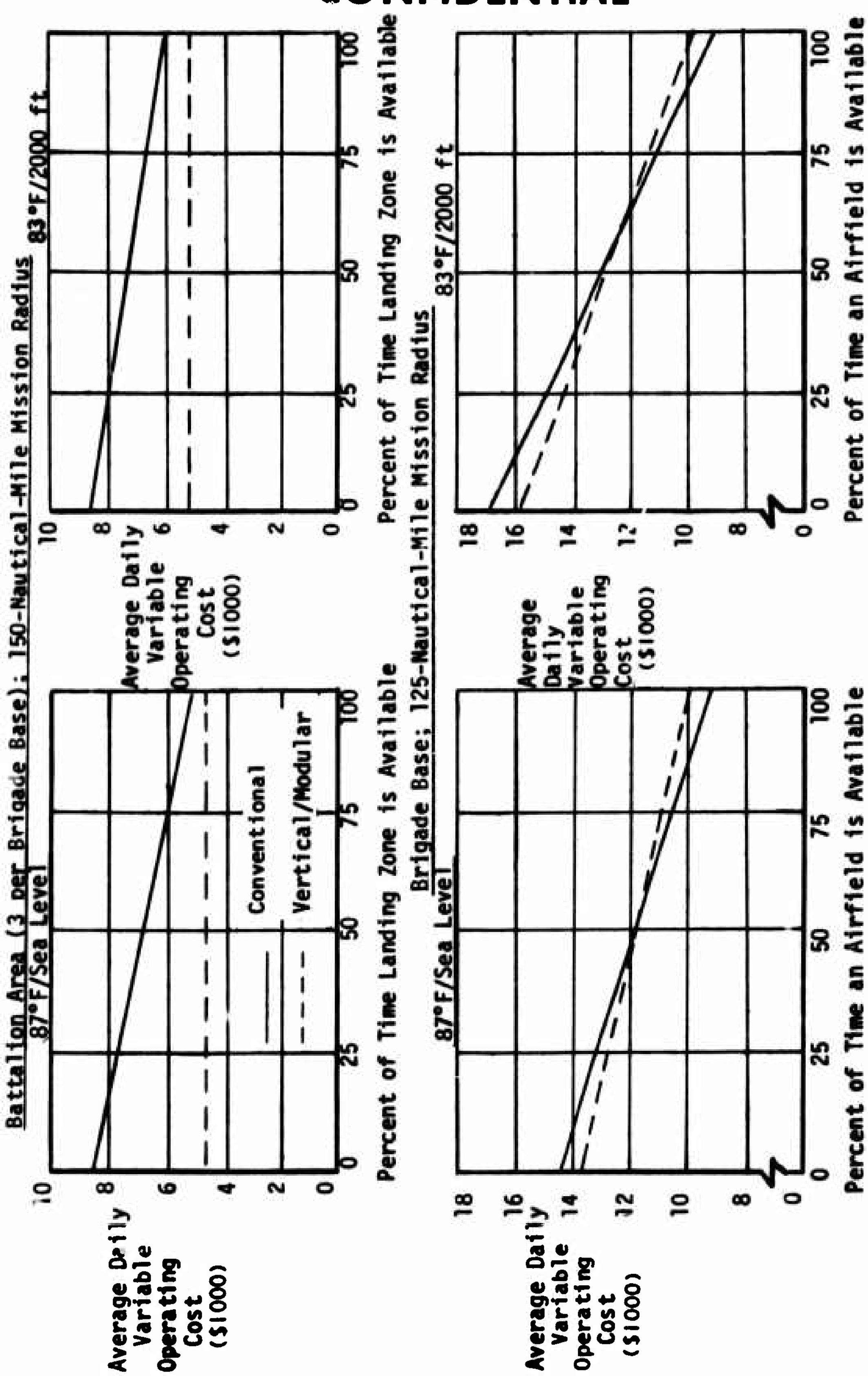

Figure 134. (C) Sensitivity of Variable Operating Costs to the Availability of a Landing Zone or Airfield Using the Least Cost Delivery Mode for Daily Resupply at Normal Combat Intensity. (U)

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(C) Two limits were investigated to determine the weight which can be safely dropped using the hover-drop (dump truck) delivery technique with the conventional system. Flight tests conducted at El Centro, California, demonstrated the capability to safely drop four 1000-pound loads in this delivery mode. Computer simulations performed by Ling-Temco Vought (Reference 18) indicated that 6600 pounds could be dropped in this delivery mode. The 6600-pound load was assumed to be within the safe flight envelope of the aircraft. This limits the aircraft payload for radii up to 330 and 220 nautical miles at 87°F/sea level and 83°F/2000 ft respectively. Beyond these radii, the aircraft payload capability is the limiting factor. If the lower 4000-pound limit had been used, the conventional cargo handling system would have been penalized for all mission radii. In contrast, the vertical/modular system, which drops cargo out the bottom, does not appreciably affect aircraft stability and full available payload can be utilized to all mission radii. For the short-radius mission, the conventional system limitations cause a large portion of the cost difference.

(U) As discussed in the "Operational Comparison" chapter, cargo damage for the conventional cargo handling system was only 2 percent, even though the cargo loads will all tip off the ramp and usually tumble on ground impact. Because the cargo will hit flat on the ground and utilize the full potential of the honeycomb cushioning material, damage is negligible for the vertical/modular cargo handling system in hover-drop delivery.

(U) Rigging for the two systems is slightly different as discussed in the "Operational Comparison" chapter. The conventional cargo handling system requires more rigging. The additional rigging weight must be reflected as a payload difference between the two systems.

(C) Airdrop Delivery (U)

(C) The airdrop delivery mode is used in the battalion area when a landing zone is not available. Since the aircraft will operate as a fixed-wing aircraft in this delivery mode, there are only very small differences in the payloads of the aircraft between two temperature/altitude cases. The relative difference in variable operating cost between the two temperature/altitude cases is because of the drop zone diameter used in each case. For the 87°F/sea level case, representative of a lowlands area in Southeast Asia, it was assumed that a 700-yard-diameter drop zone would be available. For the 83°F/2000 ft case, representative of a forested highlands area in Southeast Asia, it was assumed that a 450-yard-diameter drop zone would be available. Because the drop zone is smaller in the 83°F/2000 ft case, the cargo lost due to landing outside of the drop zone is higher, accounting for increased costs over the 87°F/sea level case for both the conventional and vertical/modular systems.

(U) The vertical/modular cargo handling system has lower costs for this delievery mode although the difference is relatively small. This difference is generally caused by the difference in the cost of the rigging between the conventional and vertical/modular cargo handling systems.

(C) As previously stated, the 83°F/2000 ft case illustrates the effect of variations in drop zone size on variable operating cost. A comparison of the differences between the conventional and vertical/modular accuracy is apparent when comparing the differences in variable operating cost between the two systems for the two different drop zone sizes (87°F/sea level versus 83°F/2000 ft). The vertical/modular system is slightly more accurate (see Operational Comparison chapter). The accuracy used is conservative because the assumed spacing of 25 yards between modules could likely be reduced after testing the system. For example, A-22 container loads stacked two high have been successfully dropped from a C-124 without entanglement of parachutes.

(U) Efficient Delivery Mode

Each system, conventional and vertical/modular, has the capability of utilizing several delivery modes. The most efficient mode depends upon the specific mission, particularly the terrain and other environmental influences at the delivery point. Since inefficient modes would not, in general, be used, the analysis must compare the use of the best modes for a given set of mission parameters for each system.

Delivery of supplies to the brigade base can be accomplished by two delivery modes depending upon the availability of a landing field. Delivery to the battalion area can be accomplished by three delivery modes depending upon the availability of a landing zone.

(U) Brigade Base Delivery

If an airfield is available, the efficient delivery mode to the brigade base is STOL-land. Of course, if an airfield is not available, the delivery must be made VTOL-land. In any event, the aircraft will always land at the brigade base because of the likelihood of transporting retrograde cargo. Figure 133 shows the element costs making up the daily variable operating cost for these two delivery modes. The lost aircraft, POL, and spares costs are higher for VTOL-land. This is because the payload of the aircraft is severely reduced in VTOL operations and the number of cycles required to meet the daily resupply requirement is increased. Figure 134 shows the daily variable operating cost for brigade base resupply plotted as a function of airfield availability.

(C) Battalion Area (U)

(U) The delivery mode for resupply of the battalion area depends upon the availability of a landing zone.

(U) If a landing zone is available, the VTOL-land delivery mode is the efficient delivery mode for the conventional cargo handling system. The reason for this is the 6600-pound limit on payload for hover-drop delivery and the cost of the damaged cargo. (See Figure 133.)

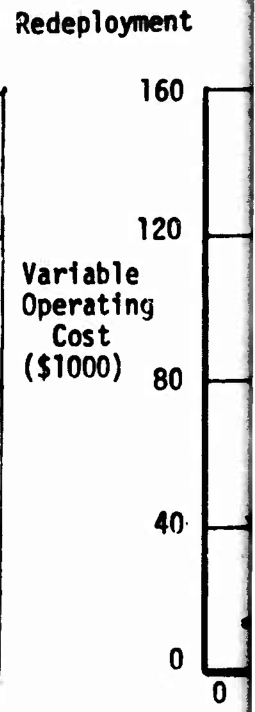
(C) Hover-drop is the preferred delivery mode with the vertical/modular system because the short time in the delivery area reduces aircraft losses to enemy fire. There are two items which were not evaluated as a portion of variable operating cost which would have impact on the decision of whether to land or hover-drop even if a landing zone is available. First, one must consider the problem of unloading cargo in a forward area where equipment is limited or non-existent; second, the aircraft may be in much more danger of being hit by enemy fire if combat troops are forced to lay aside their arms to help unload the aircraft, therefore reducing the suppressive fire on the enemy. This decision is not difficult with the vertical/modular cargo handling system, as hover-drop is the least costly delivery mode. With the conventional cargo handling system, one may choose to accept a smaller quantity of cargo, and possible damage to some of it, in return for quick unloading time with the minimum requirement for combat personnel to unload the aircraft.

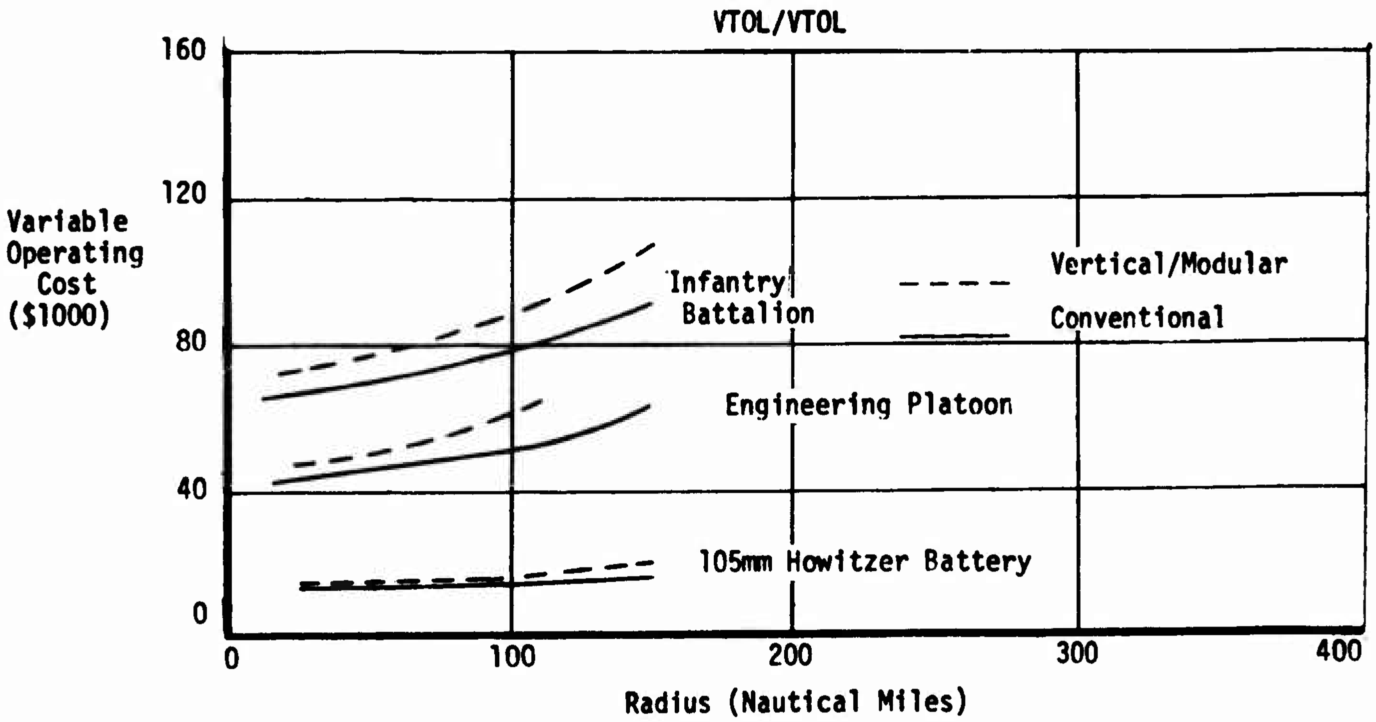
(C) If a landing zone is not available, a choice exists between hover-drop and airdrop. The operational advantage of airdrop is the higher payload available when the aircraft does not have to hover. The operational disadvantages of airdrop are: the cargo damaged due to parachute malfunctions or impact, the large drop zone required to preclude loss of supplies, and the personnel required to recover those supplies which land in the drop zone. These operational problems must be considered in addition to the high cost of packing and rigging required for airdrop. Hover-drop is limited in payload due to the limits inherent in the flight mode. The operational advantages of hover-drop are: the location to which cargo is delivered can be pinpointed (within a few feet of the desired location), cargo damage is negligible, one person on the ground is adequate to direct the aircraft to the proper location, and the recovery effort is minimal (as cargo is dropped where required). If an area large enough to airdrop cargo into is available, there is more than adequate space to hover-drop. The only thing that would restrict the use of hover-drop is if the enemy fire was so intense as to make it impossible for an aircraft to survive, in which case troops on the ground might also find it extremely difficult to recover air-dropped supplies.

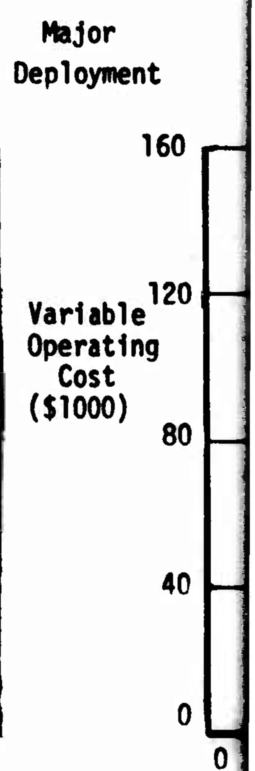
(U) Two items, not evaluated in this study, which apply to airdrop are: (1) the training of personnel to prepare cargo for airdrop, and (2) the cost of rigging materials which must be in the inventory to support the airdrop requirement. Although a thorough investigation of the factors was beyond the scope of this study, it should be noted that both would add to the cost of airdrop — already shown to be more costly compared to either VTOL-land or hover-drop on the basis of variable operating costs alone.

(C) <u>DEPLOYMENT VARIABLE OPERATING COST</u> (U)

In this study, the variable operating cost for deployment of combat units is the cost per deployment. Figures 135 and 136 show the results of the evaluation for the combat units in the battalion area for the 87°F/sea level and 83°F/2000 ft cases, respectively. Figure 137 shows the results for







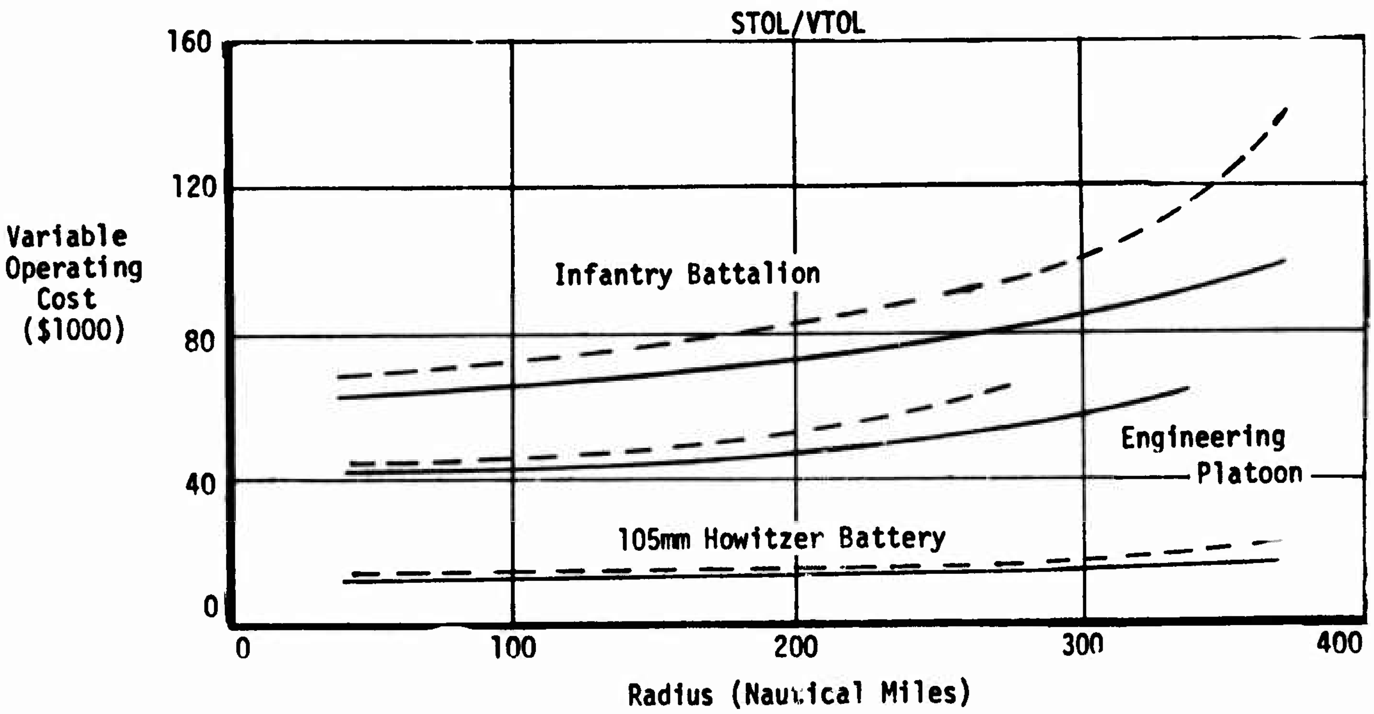
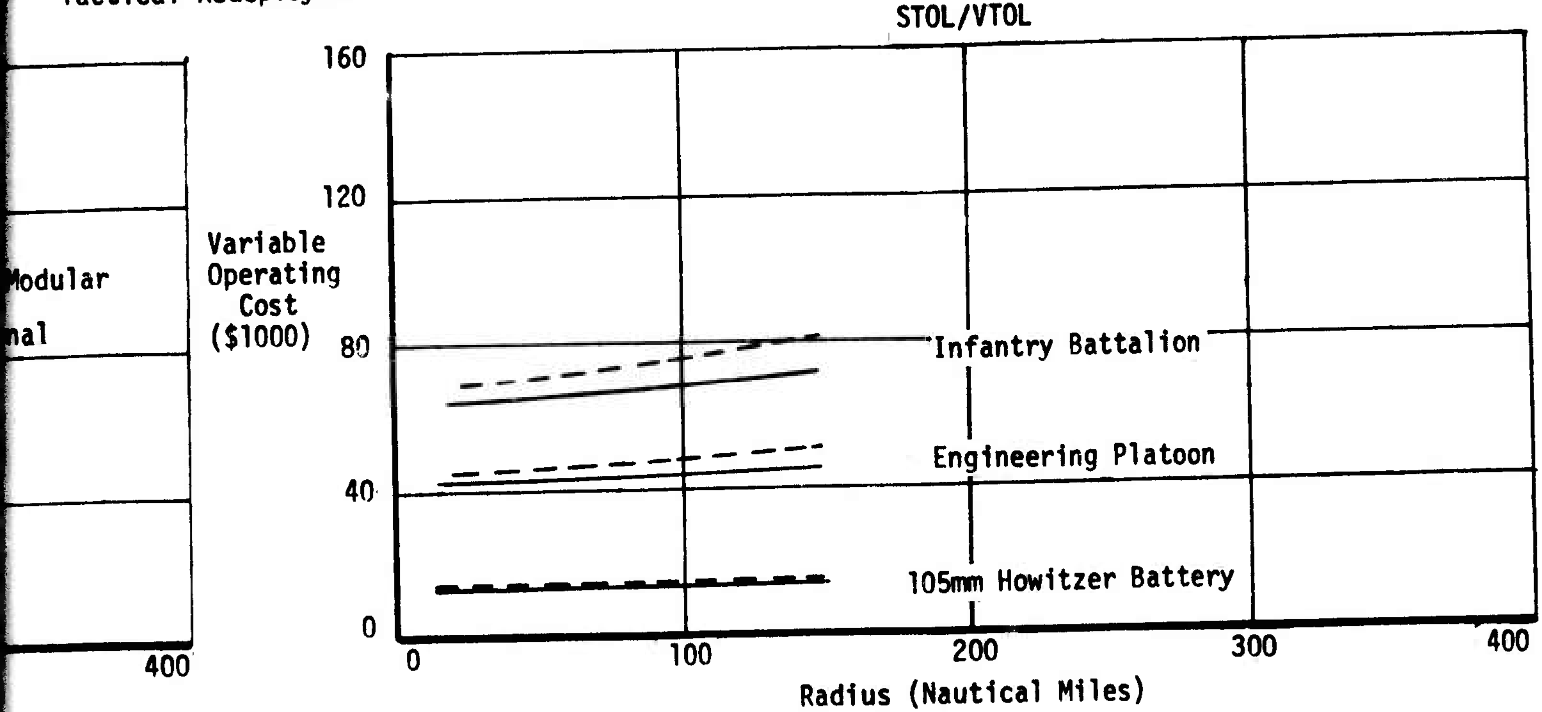
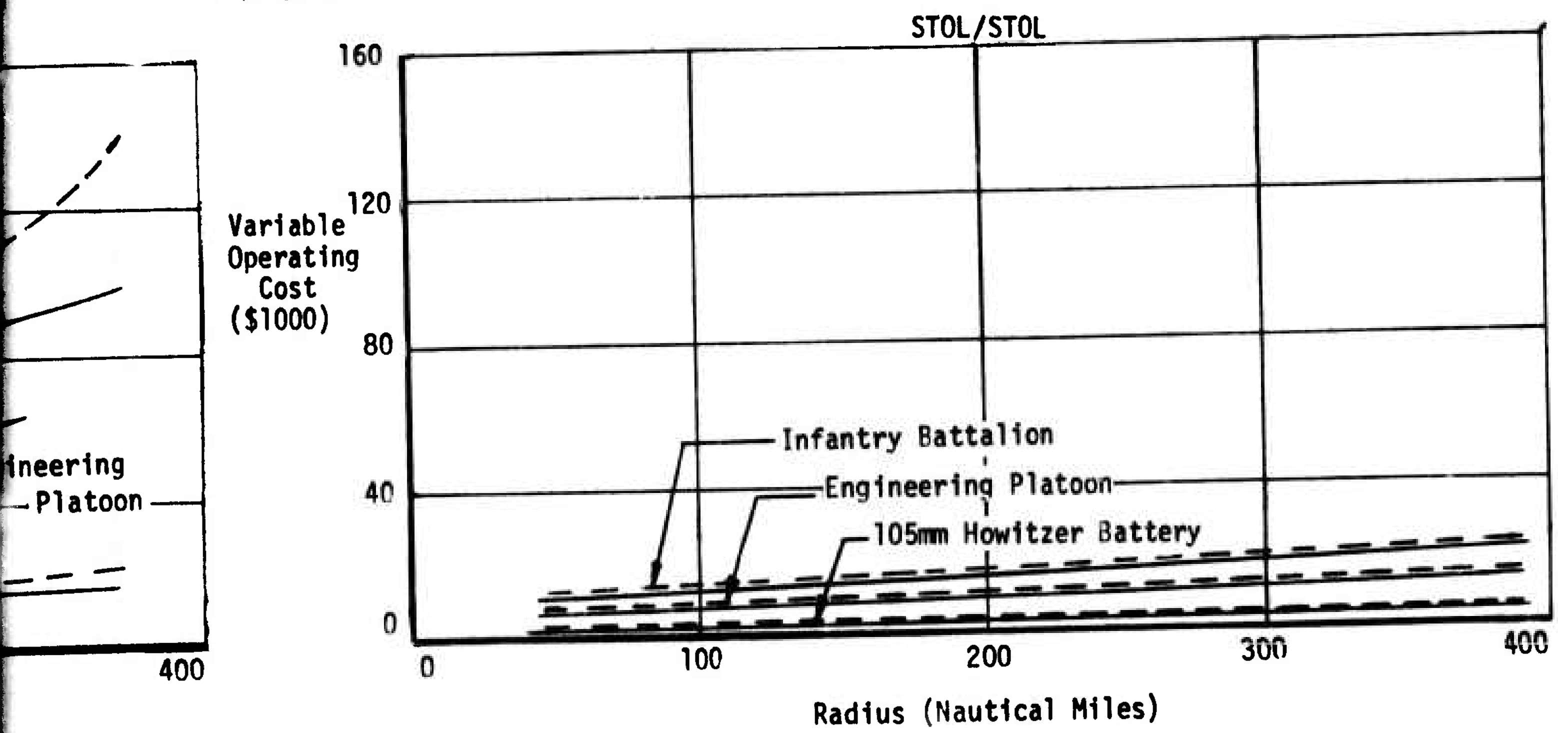


Figure 135. (C) Variable Operating Cost Versus Radius for Deployment of Combat Units by Flight Profile – Lowland Region. (U)

Tactical Redeployment



Major
Deployment



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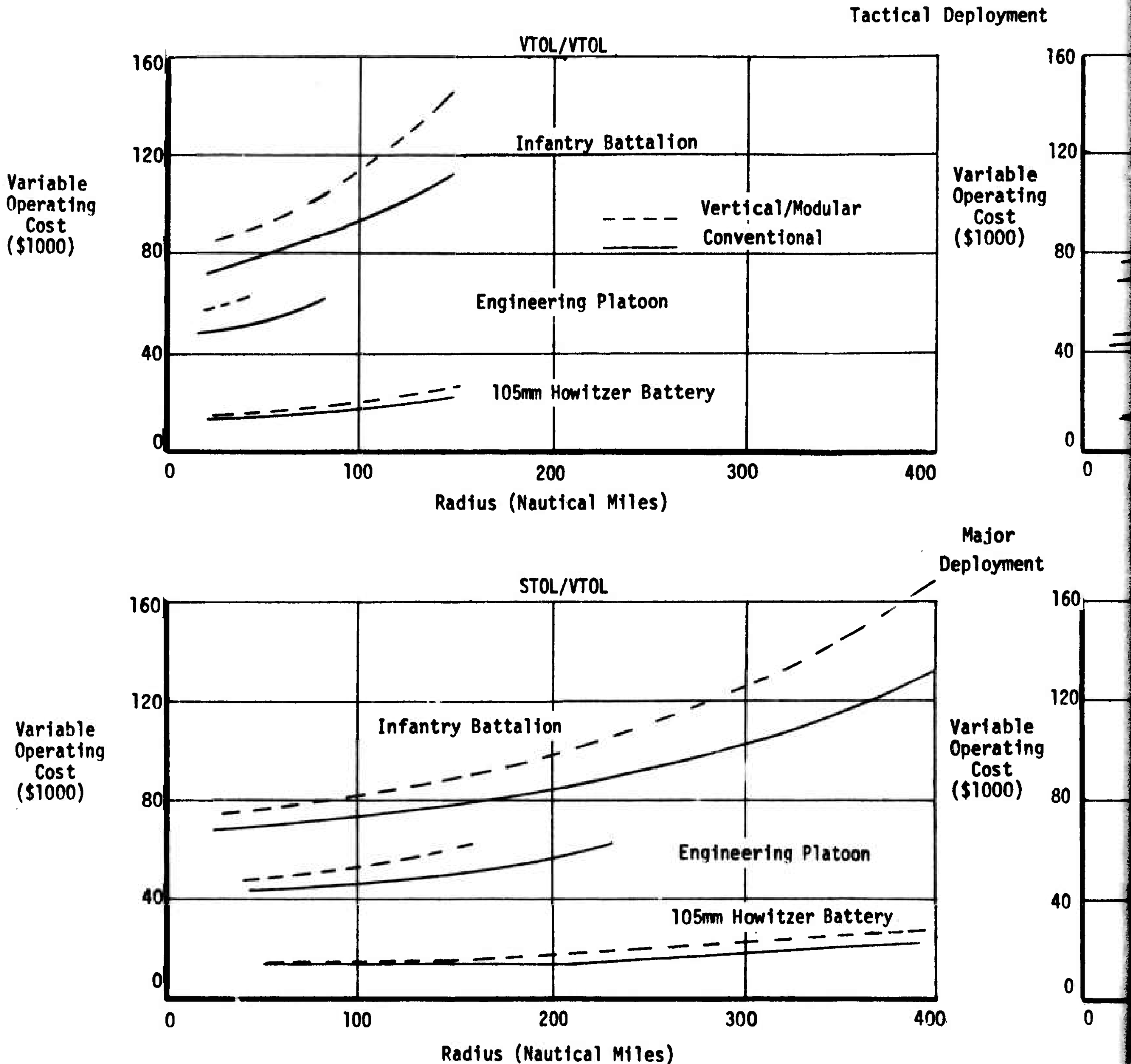
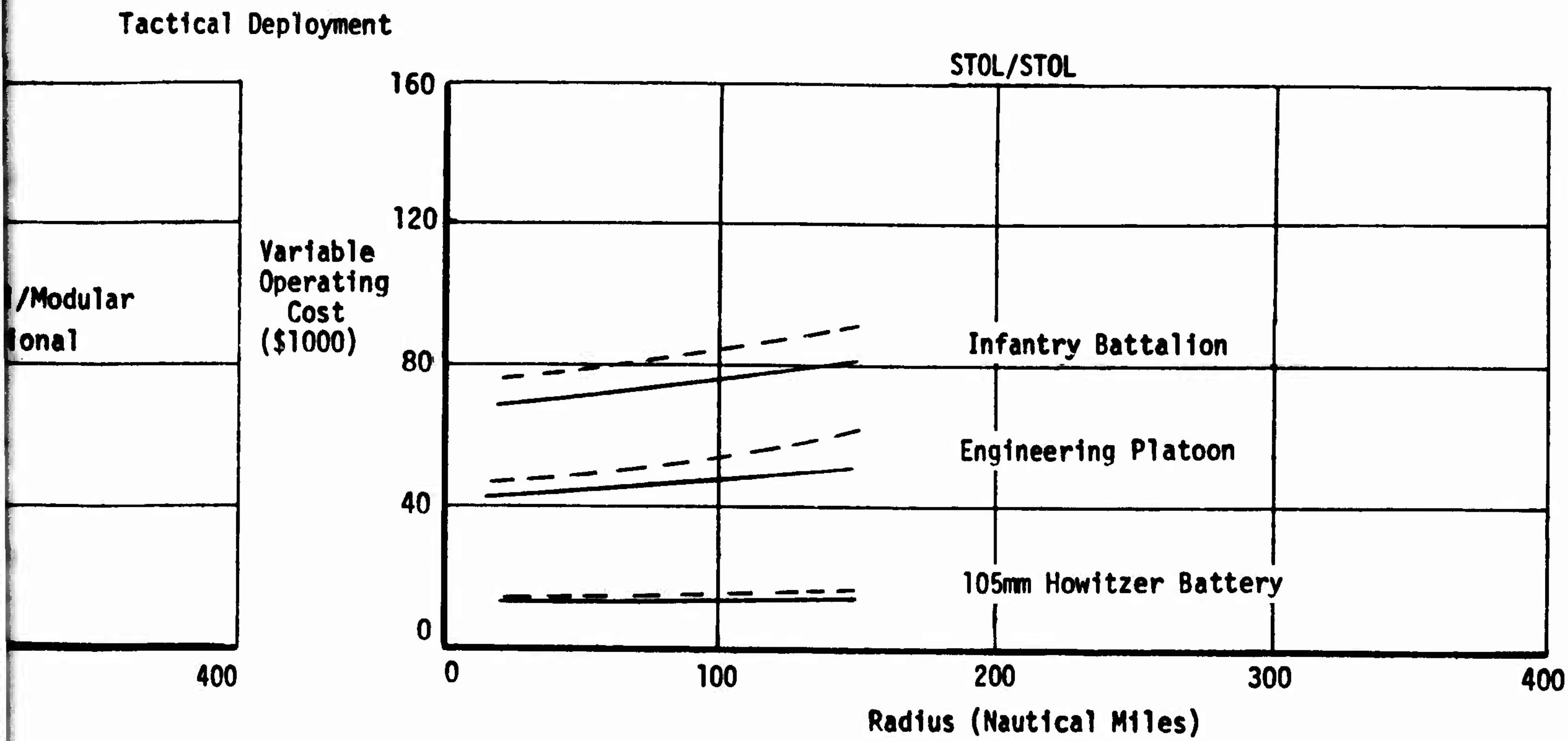
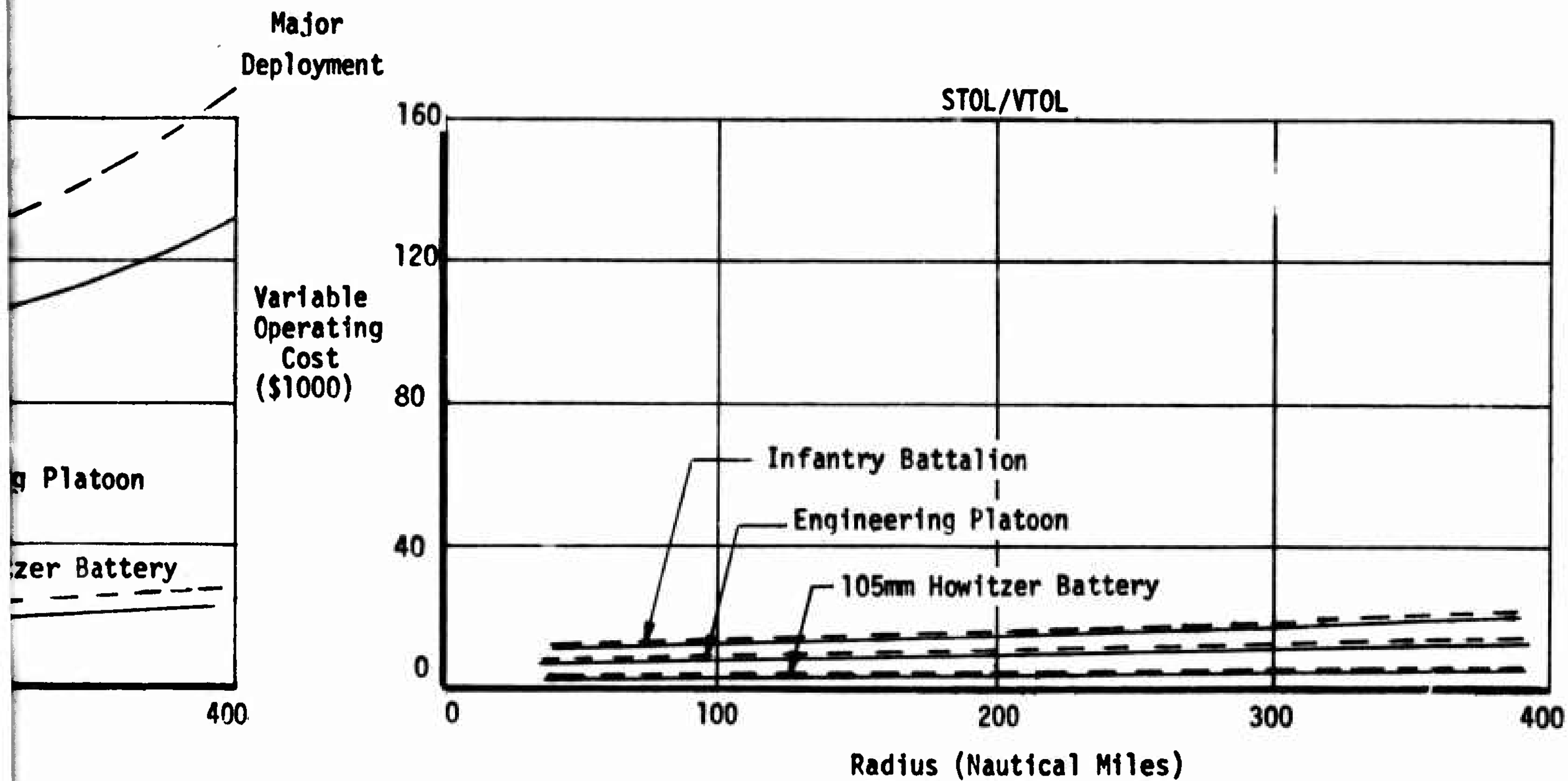


Figure 136. (C) Variable Operating Cost Versus Radius for Deployment of Combat Units by Flight Profile – Highland Region. (U)



Tactical Deployment
/Modular
onal
400
STOL/STOL
Variable
Operating
Cost
($1000)
160
120
80
40
0
Infantry Battalion
Engineering Platoon
105mm Howitzer Battery
0
100
200
300
400
Radius (Nautical Miles)



Major
Deployment
g Platoon
zer Battery
400
STOL/VTOL
Variable
Operating
Cost
($1000)
160
120
80
40
0
Infantry Battalion
Engineering Platoon
105mm Howitzer Battery
0
100
200
300
400
Radius (Nautical Miles)

ent
(U)

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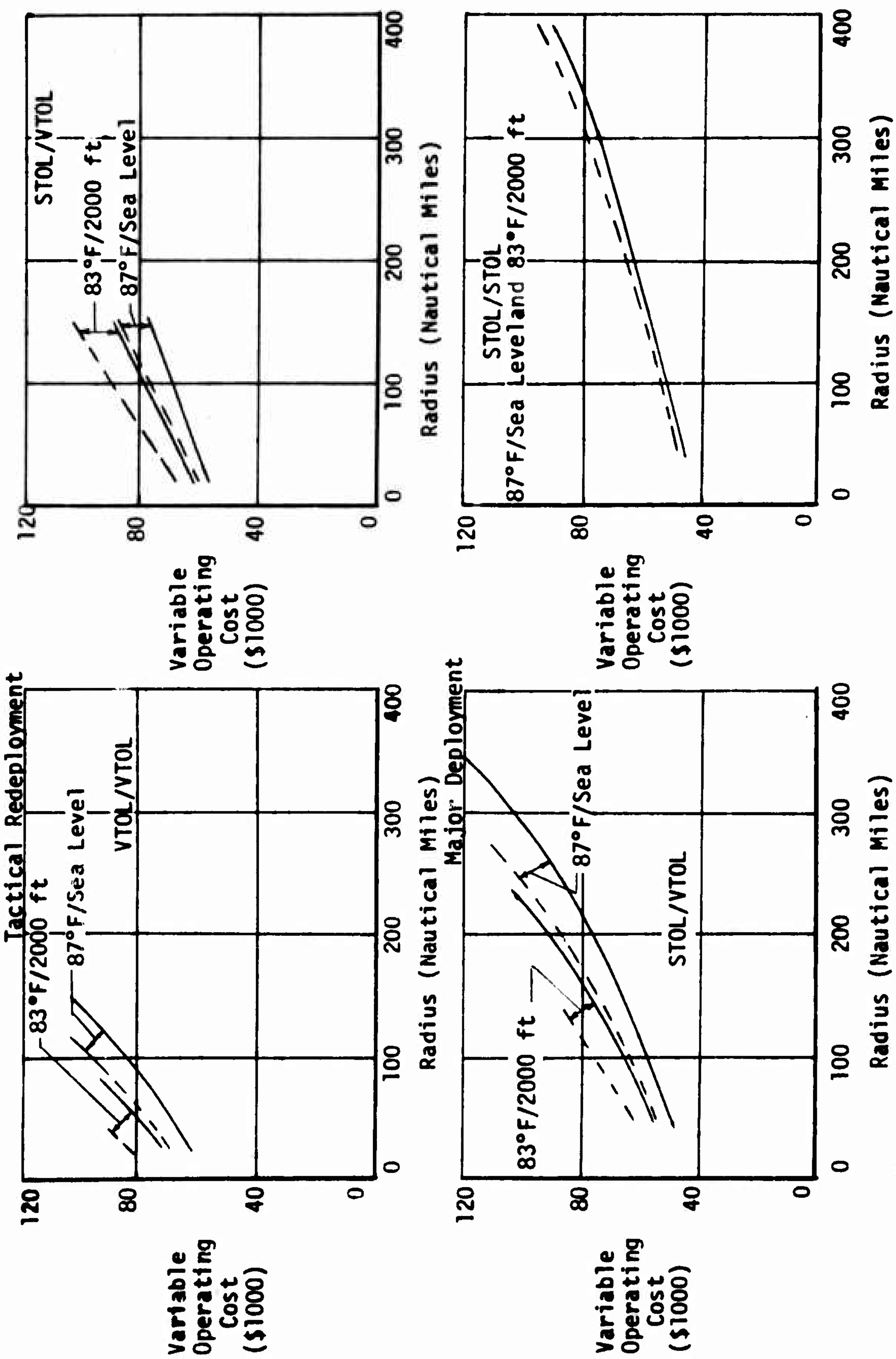


Figure 137. (C) Variable Operating Cost vs. Radius for Deployment of the Brigade Base Units by Flight Profile. (U)

brigade base units. Figure 138 shows representative illustrations of the cost elements making up the variable operating cost for deployments. The discussion of these results is by flight profile.

(C) STOL/STOL DEPLOYMENT (U)

The STOL/STOL flight profile was considered only for long-range major deployments between airfields. The difference in variable operating cost for deployments using this flight profile is very small, with the conventional cargo handling system being lower cost. This cost difference arises from the higher procurement cost of lost aircraft and spare parts for the vertical/modular cargo handling system. The payload advantage of the conventional cargo handling system is not effectively utilized, as most loads carried in deployment are volume-limited; that is, the aircraft cargo compartment is filled before the payload is used in the STOL/STOL flight profile. The results are essentially equal for both temperature/altitude cases.

(C) STOL/VTOL Deployment (U)

(U) The STOL/VTOL flight profile is used for both major deployments and tactical redeployments. The conventional cargo handling system is the lower cost for this flight profile. Cost differences between the two systems are much larger than with the STOL/STOL flight profile. In the resupply mission, the vertical/modular cargo handling system was shown to be more effective than the conventional system because it permits lowering the T/W ratio to 1.05. In deploying troops and vehicles, the vertical/modular system does not enjoy this advantage because the vehicles carried are physically too big to fit through the bottom openings and cannot be dropped. This requires the vertical/modular system to operate at a T/W ratio of 1.10. Most differences in variable operating cost between the systems in the STOL/VTOL and VTOL/VTOL flight profiles result from the additional weight of the vertical/modular cargo handling system with a smaller increase caused by higher initial costs.

(U) The sensitivity to the makeup of combat units is demonstrated in this flight profile. The engineering platoon curves for major development STOL/VTOL in Figures 135 and 136 show lower attainable radii, vis-a-vis the infantry battalion and the howitzer battery, because the 3/4-ton trucks weigh 5800 pounds each. The curves stop at the radii where the payload of the aircraft is 5800 pounds.

(C) The STOL/VTOL flight profile also shows the relative magnitude of the cost elements which make up the variable operating costs for the brigade base and battalion area units. (See Figure 138.) The brigade base deployment requires approximately 4.5 times as many cycles as the infantry battalion, but the variable operating costs are nearly equal. The cost elements show that the major variation is combat losses. The infantry battalion would be the first unit into a hostile area. Aircraft losses to enemy fire would be high. As brigade base units follow the battalions, aircraft combat losses are lower.

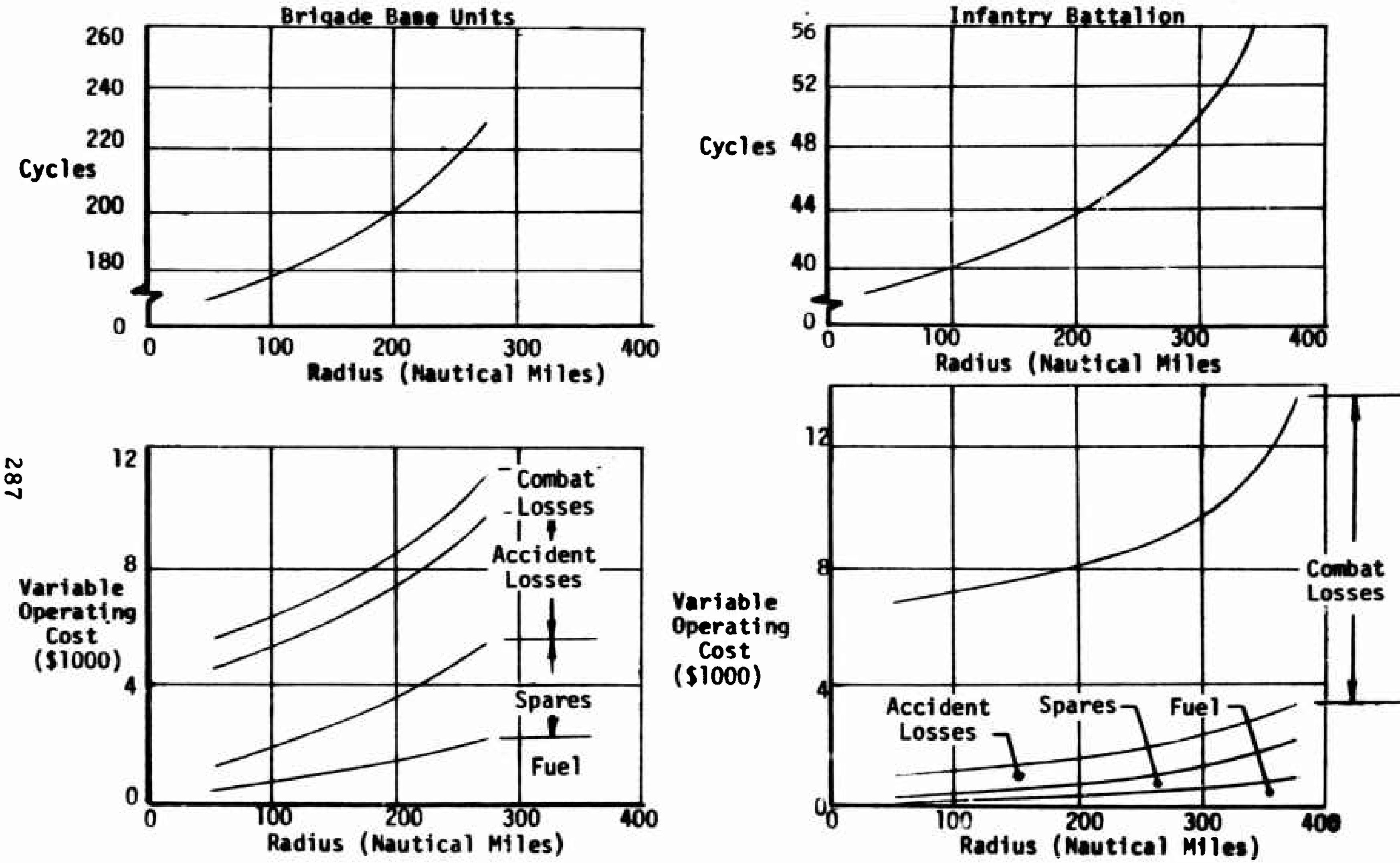


Figure 138. (C) Elemental Cost Comparison – Deployment of Brigade Base Units and Infantry Battalion, STOL/VTOL Flight Mode, Vertical/Modular Delivery System, Lowland Region. (U)

(U) VTOL/VTOL Deployment

The VTOL/VTOL flight profile is used for tactical redeployment only. This flight profile is representative of short battlefield shifts dictated by the specific tactical situation. Here again the conventional cargo handling system has lower cost. As with the STOL/VTOL flight profile, the engineering platoon and the brigade base are limited to short-radius missions by the 5800-pound 3/4-ton truck. This restriction is even more severe in VTOL/VTOL flight profile because of the low payload capability of the aircraft in this flight mode.

(U) SUMMARY: VARIABLE OPERATING COST RESULTS

The evaluation of variable operating cost has shown cost differentials between the conventional and vertical/modular systems for all missions analyzed. The conventional system is less costly for deployment missions and for resupply missions when an airfield is available. The vertical/modular system is less costly for resupply missions when an airfield is not available.

The net cost difference between the two systems is dependent upon the relative frequency of deployment and resupply operations, and on the percent of the time an airfield is available. For deployment missions the availability of an airfield minimizes the cost advantage of the conventional system. For brigade base resupply missions, the least cost alternative is the vertical/modular system when an airfield is available less than 60 percent of the time. The vertical/modular system is always the preferred system for battalion area resupply.

These quantitative results are conservative from the point of view of the vertical/modular system. The following assumptions favored the conventional system:

1. Aircraft lost
   - equal loss rates assumed for resupply operations, despite the cargo-jettison capability of the vertical/modular system.
   - high loss rates for deployment operations (battalion area units), which emphasize the additional cycles required with the heavier vertical/modular system.
2. Cargo lost
   - large exit-spacing between modules assumed for airdrop with the vertical/modular system, degrading its delivery accuracy.
   - low (2 percent) cargo impact damage for hover-drop with the conventional system.

3. Productivity - T/W ratio reduced only to 1.05 for the resupply with the vertical/modular system.

4. Multiple stops - not evaluated. The conventional system was not penalized for the time, manpower, and aircraft exposure associated with rearranging cargo between stops to (1) remove cargo which could not be placed at the rear of the aircraft due to center-of-gravity limitations, or (2) re-establish the aircraft weight and balance after part of the cargo has been unloaded.

(C) EXTENSION OF ANALYSIS: 10-YEAR TOTAL SYSTEM COST (U)

(U) A 10-year total system cost may be based on an infinite number of combinations of the cost elements and mission parameters discussed in previous chapters. Subsequent sections of this chapter are primarily the domain of the military decision maker, not of the systems analyst. The method presented for combining costs and mission parameters to achieve a total system cost is designed to permit independent variation and examination of the effect of the following on the variable part of total system cost:

1. Wartime and peacetime operations.

2. Resupply and deployment operations.

3. Mixes of the number and type of units supplied or transported and the delivery mode or flight profile employed, based on the appropriate radius, airfield or landing zone availability, and combat intensity or type of deployment.

4. Average operating temperature/altitude.

Figure 139 shows the overall flow of the total system cost calculations, beginning with the primary output of the evaluation, variable operating cost. Figure 140 shows the detail flow of the analysis.

(C) VARIABLE OPERATING COST: WARTIME MONTH (U)

(U) The variable operating costs for a wartime month are calculated independent of the number of aircraft possessed. Resupply and deployment calculations are made separately.

Resupply Operations

(U) Table XLIX presents the variable operating costs assumed for a day of wartime lull. These are based on a constant 60 flight hours per day, independent of the number of aircraft.

(U) Tables L and LI show the derivation of variable operating cost per month for wartime resupply operations. These costs are based on using the least cost delivery mode for both the conventional and vertical/modular delivery systems. Which delivery mode exhibits least cost depends on the airfield and landing zone availability. Conservative values, generally unfavorable to the vertical/modular system, were assumed based on the South Vietnam data presented in the "Wartime Evaluation Mission" chapter, in the absence of detailed data, analysis, or experienced military judgment.

(C) An airfield was assumed to exist at the brigade bases 100 percent of the time at maximum combat intensity and 93 percent of the time at normal combat intensity. No airfields were assumed available in the battalion areas. A landing zone was assumed available 100 percent of the time in the 87°F/sea level region and at maximum combat intensity in the 83°F/2000 ft region, but only 87 percent of the time at normal combat intensity in the 83°F/2000 ft region.

(C) The average distances from the logistic support base to the brigade base (125 N Mi) and battalion area (150 N Mi) from Table I were used.

(C) For ease of calculation, all battalion areas and 2 brigade bases were assumed simultaneously committed at the same combat intensity. This assumption can be interpreted to mean: all units at maximum combat intensity 1 day per month, normal for 14 days, and lull for 15 days; 1 brigade base and 3 battalion areas are engaged in combat, but for all 30 days, while the second brigade is uncommitted; or any other of numerous interpretations.

(U) Deployment Operations

Separately, but in light of the resupply calculations, a mix of deployment operations per wartime month was developed as shown in Tables LII and LIII. This block of deployment missions, like the resupply missions, is assumed to be performed in an unspecified sequence throughout the nominal wartime month. Most of the deployment missions in the mix are major deployments (longer radius) as appropriate for an XC-142A type of aircraft supporting an airmobile division possessing considerable organic helicopter capacity for shorter-range movements.

(C) AIRCRAFT COMPLEMENT (U)

Since the delivery system concepts evaluated in this study are intended primarily for direct resupply operations from the logistic support base to the brigade area, the size of the aircraft complement (57 conventional or 51 vertical/modular delivery systems) is based on a resupply criterion, namely the ability to either:

1. Provide sustained resupply to two brigade areas with: normal combat intensity; 83°F/2000 ft; extended distances from the logistic support base (200 N Mi to battalion area, 150 N Mi to brigade base); VTOL-land used for all deliveries; and a criterion for determining the number of aircraft of 4 hours daily utilization per complement aircraft. — or

2. Meet a simultaneous peak resupply surge to two brigade areas under the same conditions as above, except that the criterion for determining the number of aircraft changes to a 12-hour operating day and a 75-percent availability.

Figure 141 compares the number of aircraft required versus the radius upon which the requirement is based. This figure also illustrates the

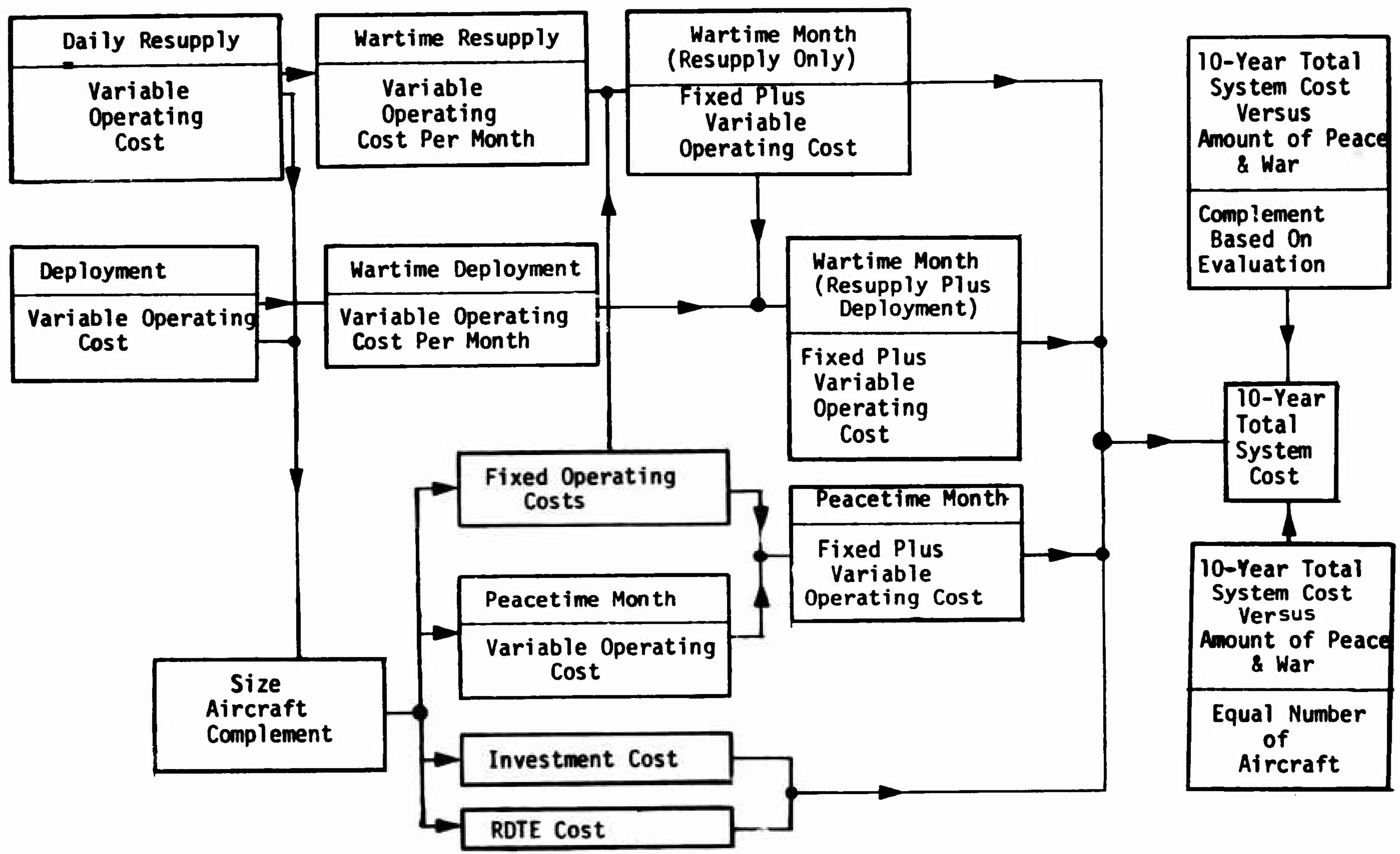


Figure 139. (U) Overall Flow of Total System Cost Calculation.

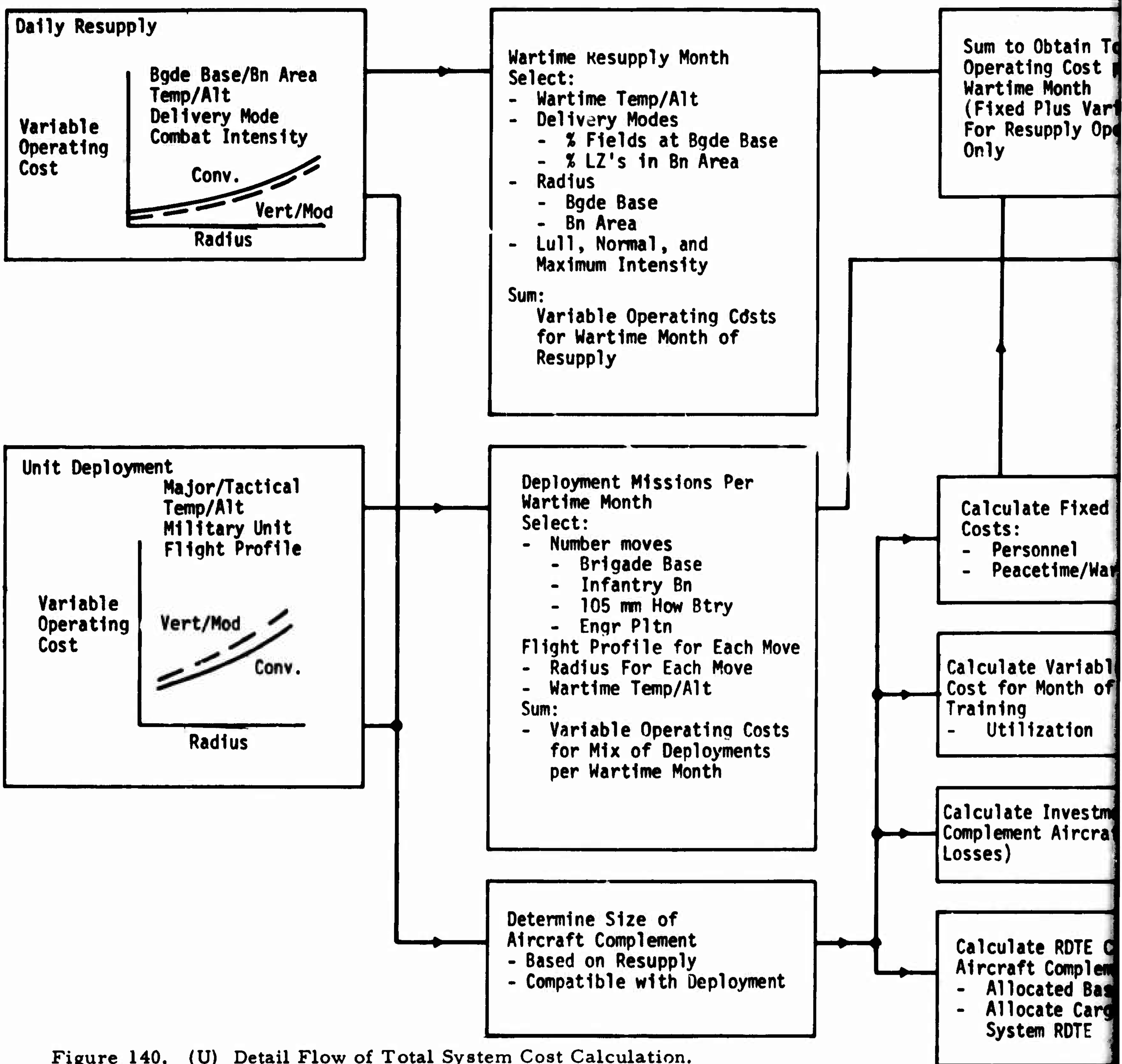
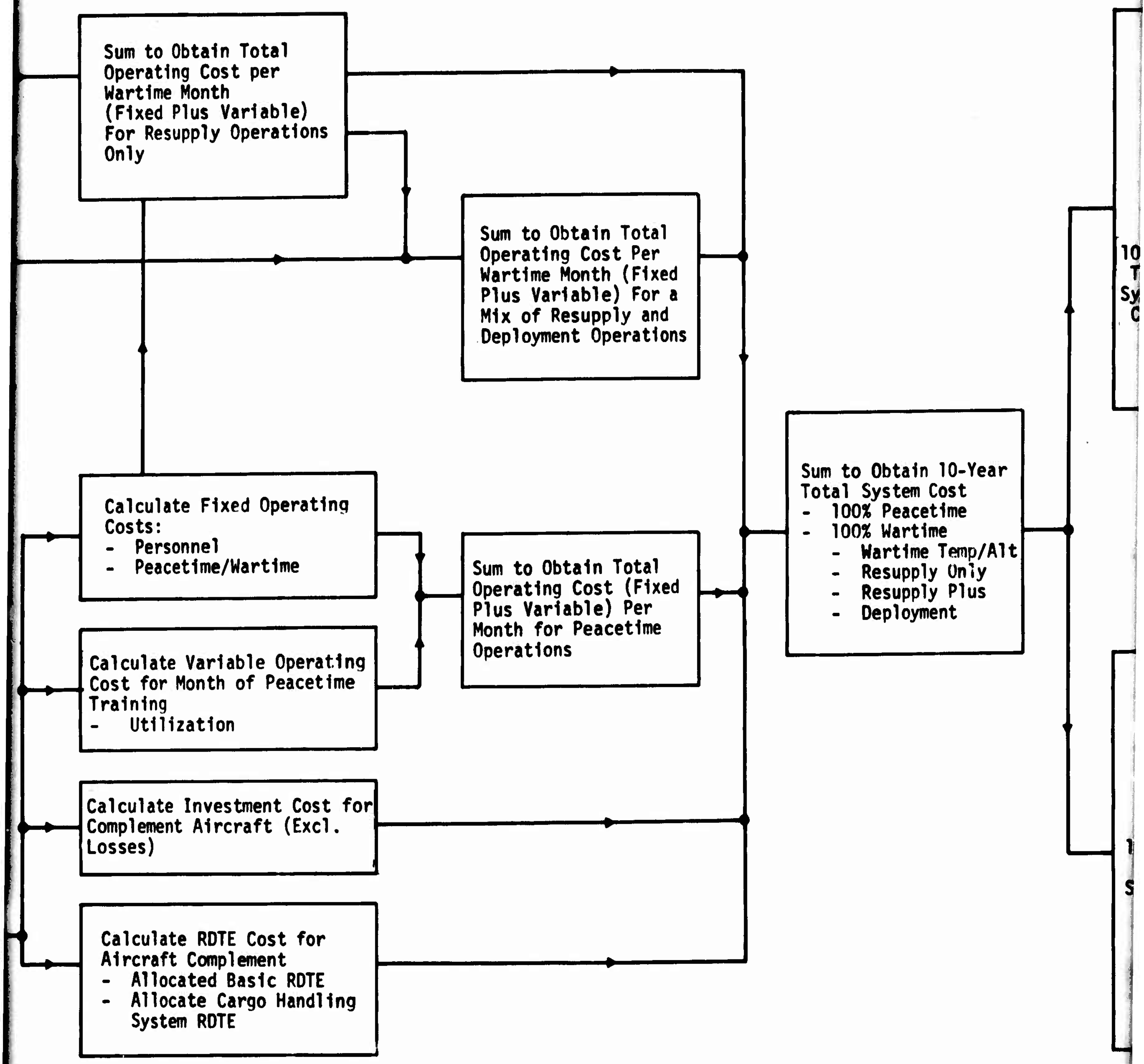
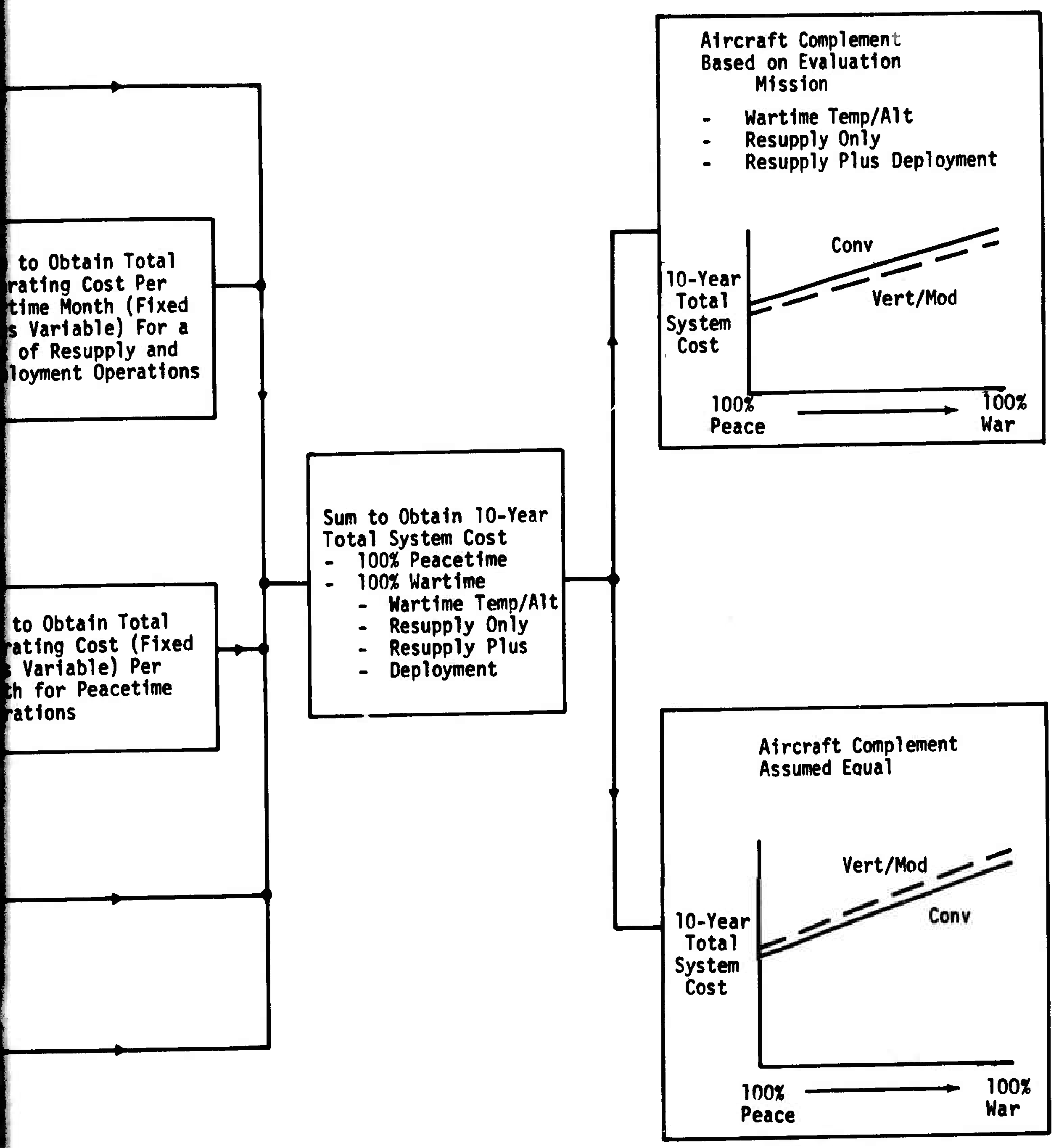


Figure 140. (U) Detail Flow of Total System Cost Calculation.


Sum to Obtain Total Operating Cost per Wartime Month (Fixed Plus Variable) For Resupply Operations Only
Sum to Obtain Total Operating Cost Per Wartime Month (Fixed Plus Variable) For a Mix of Resupply and Deployment Operations
Calculate Fixed Operating Costs:
- Personnel
- Peacetime/Wartime
Calculate Variable Operating Cost for Month of Peacetime Training
- Utilization
Sum to Obtain Total Operating Cost (Fixed Plus Variable) Per Month for Peacetime Operations
Sum to Obtain 10-Year Total System Cost
- 100% Peacetime
- 100% Wartime
- Wartime Temp/Alt
- Resupply Only
- Resupply Plus
- Deployment
Calculate Investment Cost for Complement Aircraft (Excl. Losses)
Calculate RDTE Cost for Aircraft Complement
- Allocated Basic RDTE
- Allocate Cargo Handling System RDTE
10
T
Sy
C
1
S

2



to Obtain Total
rating Cost Per
time Month (Fixed
s Variable) For a
of Resupply and
loyment Operations
to Obtain Total
rating Cost (Fixed
Variable) Per
h for Peacetime
rations
Sum to Obtain 10-Year
Total System Cost
- 100% Peacetime
- 100% Wartime
- Wartime Temp/Alt
- Resupply Only
- Resupply Plus
- Deployment
Aircraft Complement
Based on Evaluation
Mission
- Wartime Temp/Alt
- Resupply Only
- Resupply Plus Deployment
Conv
Vert/Mod
10-Year
Total
System
Cost
100%
Peace
100%
War
Aircraft Complement
Assumed Equal
Vert/Mod
Conv
10-Year
Total
System
Cost
100%
Peace
100%
War

3

TABLE XLIX (C)
WARTIME LULL VARIABLE OPERATING COST PER DAY (U)

Cost Element	Cost Per Day[1] Conventional	Cost Per Day[1] Vertical/Modular
Petroleum, Oil, and Lubricants (POL)[2]	$ 2,400	$ 2,400
Recurring Spares[3]	3,600	3,780
Lost Aircraft (Accidents)[4]	7,200	7,500
Total	$ 13,200	$ 13,680

[1]Independent of the number of conventional delivery system aircraft and vertical/modular delivery system aircraft.

[2]60 flight hours per day; $40 per flight hour for fuel.

[3]$60 and $63 per flight hour for conventional and vertical/modular systems, respectively.

[4]Accidental losses $120 and $125 per flight hour for the conventional and the vertical/modular system, respectively.

TABLE L (C)
WARTIME RESUPPLY: VARIABLE OPERATING COST PER MONTH ($87^{o}F/SL$) (C)

Combat Intensity		Six Battalion Areas		Two Brigade Bases		
		No Landing Zone	Landing Zone	No Airfield	Airfield	Total
Conventional Delivery System		Hover-drop	VTOL-land	VTOL-land	STOL-land	
Lull:	Cost Per Day ($)	-	-	-	-	13,200
	Number Days	-	-	-	-	14
	Cost Per Month ($)	-	-	-	-	184,800
Normal:	Cost Per Day ($)	51,282	30,642	29,720	18,248	-
	Number Days	0	15	1	14	15
	Cost Per Month ($)	0	459,630	29,720	255,472	744,822
Maximum:	Cost Per Day ($)	128,976	94,590	64,400	40,166	-
	Number Days	0	1	0	1	1
	Cost Per Month ($)	0	94,590	0	40,166	134,756
Total Cost Per Month		$ 0	554,220	29,720	295,638	1,064,378
Vertical/Modular Delivery System		Hover-drop	Hover-drop	VTOL-land	STOL-land	
Lull:	Cost Per Day ($)	-	-	-	-	13,680
	Number Days	-	-	-	-	10
	Cost Per Month ($)	-	-	-	-	191,520
Normal:	Cost Per Day ($)	28,044	28,044	27,460	19,780	-
	Number Days	0	15	1	14	15
	Cost Per Month ($)	0	420,660	27,460	276,920	725,040
Maximum:	Cost Per Day ($)	73,134	73,134	60,800	43,620	-
	Number Days	0	1	0	1	1
	Cost Per Month ($)	0	73,134	0	43,620	116,754
Total Cost Per Month		$ 0	493,794	27,460	320,540	1,033,314

TABLE LI (C)
WARTIME RESUPPLY: VARIABLE OPERATING COST PER MONTH (83°F/2000 FT) (C)

Combat Intensity		Six Battalion Areas: No Landing Zone	Six Battalion Areas: Landing Zone	Two Brigade Bases: No Airfield	Two Brigade Bases: Airfield	Total
Conventional Delivery System		Hover-drop	VTOL-land	VTOL-land	STOL-land	
Lull:	Cost Per Day ($)	-	-	-	-	13,200
	Number Days	-	-	-	-	14
	Cost Per Month ($)	-	-	-	-	184,800
Normal:	Cost Per Day ($)	51,222	36,312	34,068	18,098	-
	Number Days	2	13	1	14	15
	Cost Per Month ($)	102,444	472,056	34,068	253,372	861,940
Maximum:	Cost Per Day ($)	128,844	112,266	75,440	39,766	-
	Number Days	0	1	0	1	1
	Cost Per Month ($)	0	112,266	0	39,766	152,032
Total Cost Per Month ($)		102,444	584,322	34,068	293,138	1,145,972
Vertical/Modular Delivery System		Hover-drop	Hover-drop	VTOL-land	STOL-land	
Lull:	Cost Per Day ($)	-	-	-	-	13,680
	Number Days	-	-	-	-	14
	Cost Per Month ($)	-	-	-	-	191,520
Normal:	Cost Per Day ($)	31,356	31,356	31,888	19,596	-
	Number Days	2	13	1	14	15
	Cost Per Month ($)	62,712	407,628	31,888	274,344	776,572
Maximum:	Cost Per Day ($)	82,182	82,182	70,680	43,200	-
	Number Days	0	1	0	1	1
	Cost Per Month ($)	0	82,182	0	43,200	125,382
Total Cost Per Month ($)		62,712	489,810	31,888	317,544	1,093,474

TABLE LII (C)
WARTIME DEPLOYMENT: VARIABLE OPERATING COST PER MONTH
(87°F/SL) (C)

	Radius N Mi	Bdge Base Moves	Bdge Base Cost	Infantry Bn Moves	Infantry Bn Cost	Engr Pltn Moves	Engr Pltn Cost	How Btry Moves	How Btry Cost	Total Cost
Conventional Delivery System										
Tactical Redeployment										
VTOL-VTOL	25	0	-	0	-	1	43,895	2	28,060	71,955
STOL-VTOL	75	0	-	1	67,618	0	-	1	14,240	81,858
Major Deployment										
STOL-VTOL	150	1	67,390	3	207,810	3	133,290	3	42,606	451,096
STOL-STOL	300	1	75,380	3	53,520	3	34,680	3	11,568	175,148
Total Cost/Month ($)			142,770		328,948		211,865		96,474	780,057
Vertical/Modular Delivery System										
Tactical Redeployment										
VTOL-VTOL	25	0	-	0	-	1	47,398	2	29,206	76,604
STOL-VTOL	75	0	-	1	72,308	0	-	1	14,820	87,128
Major Deployment										
STOL-VTOL	150	1	75,030	3	233,010	3	149,796	3	'4,388	502,224
STOL-STOL	300	1	78,380	3	55,380	3	35,910	3	11,982	181,652
Total Cost/Month ($)			153,410		360,698		233,104		100,396	847,608

TABLE LIII (C)
WARTIME DEPLOYMENT: VARIABLE OPERATING COST PER MONTH
(83^{o}F/2000 FEET) (C)

	Radius N Mi	Bdge Base Moves	Bdge Base Cost	Infantry Bn Moves	Infantry Bn Cost	Engr Pltn Moves	Engr Pltn Cost	How Btry Moves	How Btry Cost	Total Cost
Conventional Delivery System										
Tactical Redeployment										
VTOL-VTOL	25	0	-	0	-	1	49,077	2	28,052	77,129
STOL-VTOL	75	0	-	1	74,799	0	-	1	14,244	89,043
Major Deployment										
STOL-VTOL	150	1	77,380	3	234,150	3	148,914	3	42,582	503,026
STOL-STOL	300	1	75,350	3	53,310	3	34,560	3	11,520	174,740
Total Cost/Month ($)			152,730		362,259		232,551		96,398	843,938
Vertical/Modular Delivery System										
Tactical Redeployment										
VTOL-VTOL	25	0	-	0	-	1	58,380	2	29,216	87,596
STOL-VTOL	75	0	-	1	81,491	0	-	1	14,824	96,315
Major Deployment										
STOL-VTOL	150	1	89,920	3	266,160	3	183,000	3	49,647	588,727
STOL-STOL	300	1	78,550	3	55,170	3	35,790	3	11,934	181,444
Total Cost/Month ($)			168,470		402,821		277,170		105,621	954,082

difference in the size of the aircraft complement if it were based on hover-drop in the battalion area or on STOL-land at the brigade base instead of on VTOL-land at both locations. Data is presented in Appendix II to permit selection of several bases for determining the number of aircraft. Table LIV gives 10 possible ways to determine the size of the aircraft complement based on resupply operations and the radii from Reference 1. The specific resupply criterion used was chosen in light of the number of aircraft required for deployments in a single lift, a single day, and various combinations of lifts and days. Table LV shows the number of aircraft required for several representative deployments; that is, representative in light of the capabilities of the XC-142A and its use as defined for this study. Examination of this table will show that 57 conventional and 51 vertical/modular delivery system aircraft are generally compatible with deployment requirements.

(U) FIXED PLUS VARIABLE OPERATING COSTS: PEACETIME AND WARTIME

Table LVI summarizes the fixed operating costs based on the factors presented in the "Cost Analysis" chapter and the aircraft complements derived in the previous section. The information is arranged to facilitate extending the analysis, or updating it based on additional information.

Continuing the development of total system cost, the total (fixed plus variable) operating cost per month for peacetime operations is shown in Table LVII and for wartime operations in Table LVII. The wartime operating costs are shown for resupply only and for resupply plus deployment, and are directly determined from Tables L, LI, LII, and LIII.

(C) 10-YEAR TOTAL SYSTEM COST: PEACETIME AND WARTIME (U)

(U) The final summation to achieve a 10-year total system cost is shown in Table LVIX. For comparative purposes, 57 vertical/modular delivery systems are also included at the right of the table. Table LX gives the fixed and variable parts of total system cost. The information from these tables is portrayed graphically in Figure 142.

(U) Based on the mix of missions used for the calculations, the main conclusion is that the vertical/modular and conventional systems exhibit slight but inconclusive cost differences. When procured and operated for resupply, the vertical/modular system is about 7 percent less costly than the conventional system. If equal numbers of aircraft are procured and operated for resupply, the conventional system is about 2 percent less costly than the vertical/modular system (Table LXI). If the 10-year costs are based on resupply plus some support of organic helicopters in deployment operations, the two above percentages change to about 4 percent and 3 percent, in favor of the vertical/modular system and the conventional system, respectively.

(U) The magnitude of these cost differences depends on the mix of deployment and resupply operations and on the airfield availabilities assumed. As more deployment missions are included, the vertical/modular system

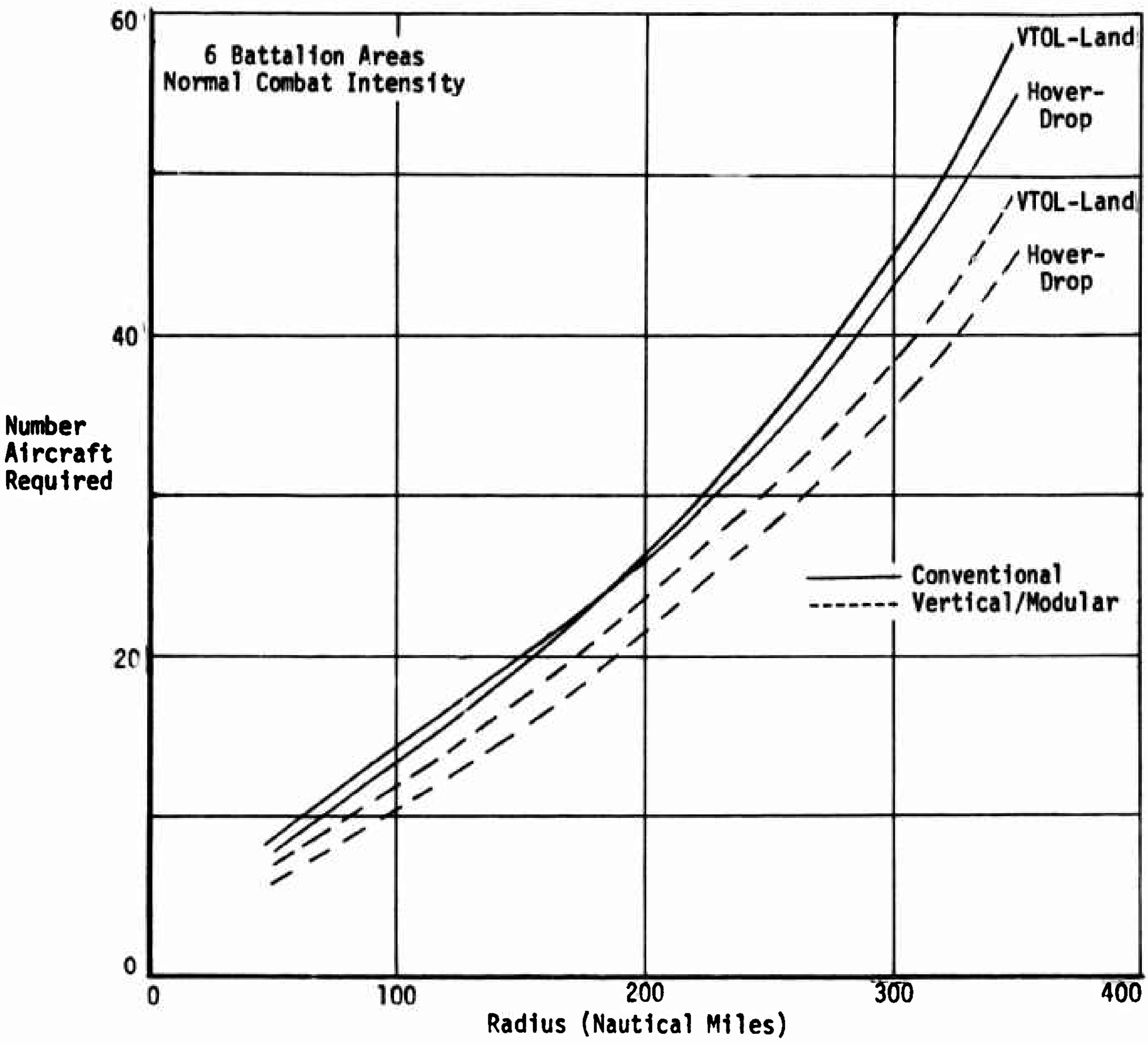
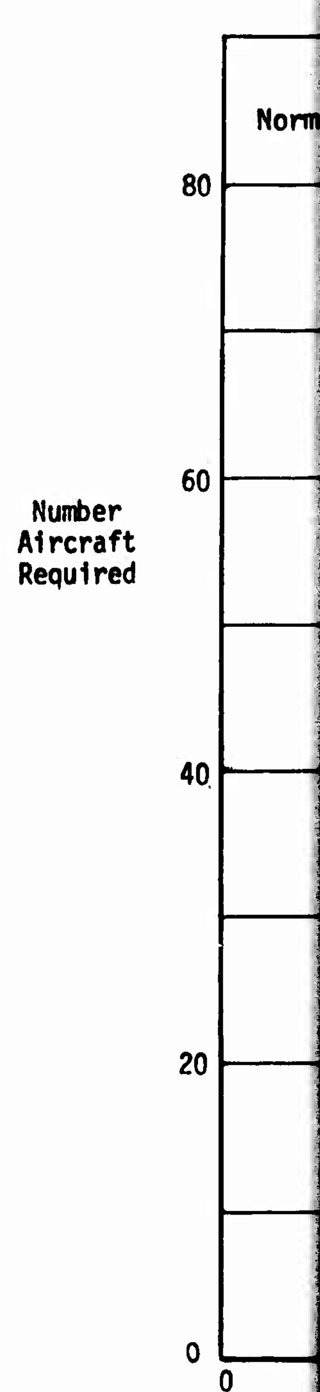
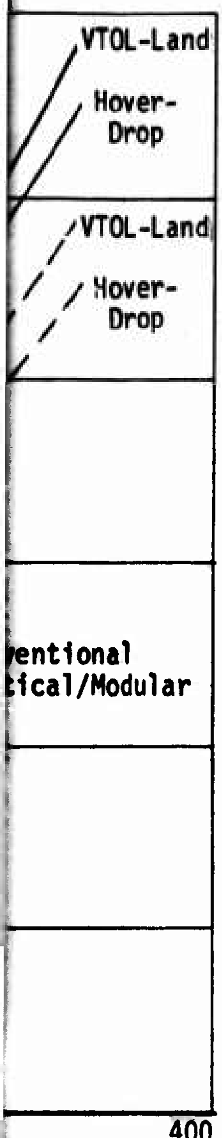
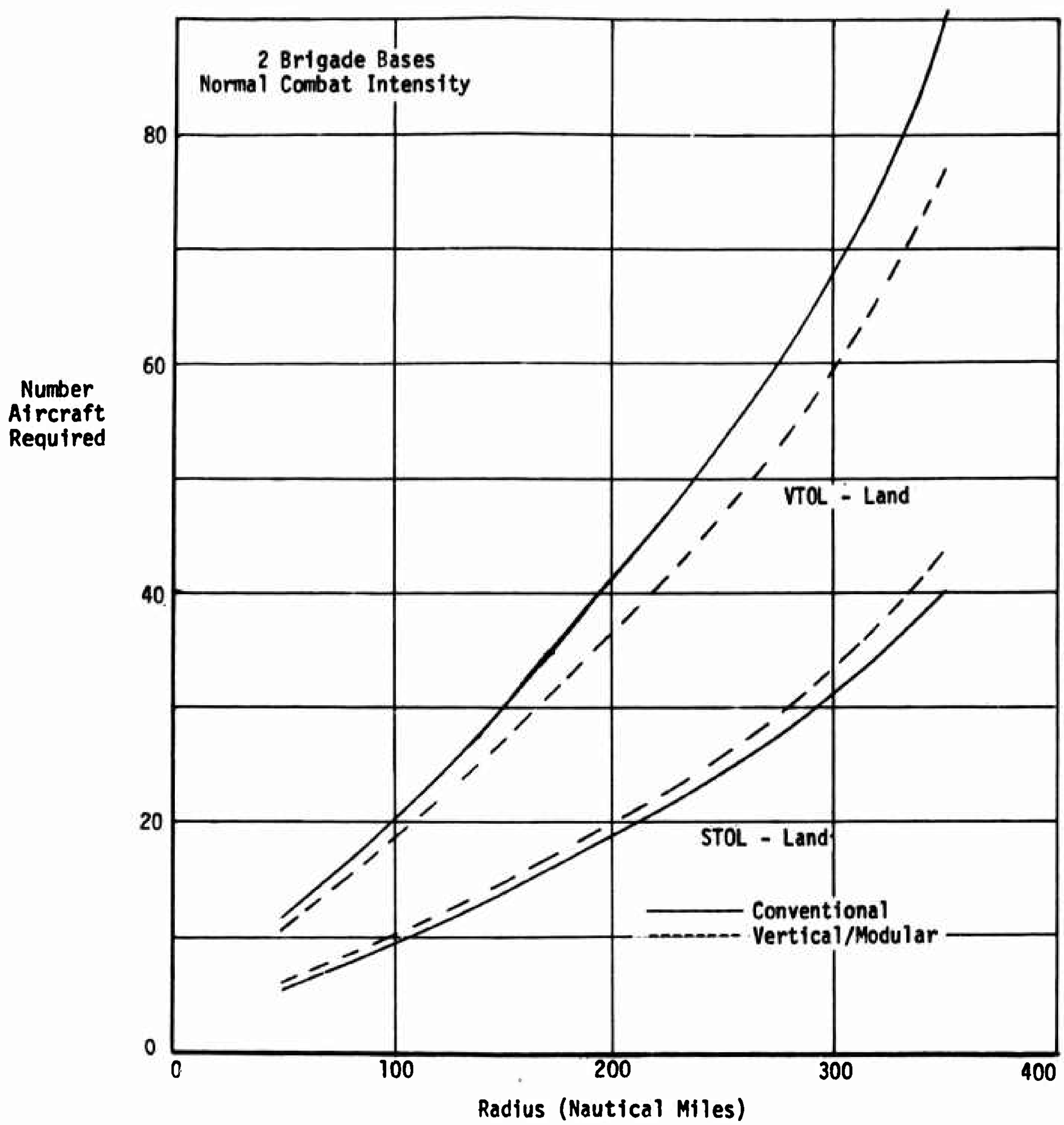


Figure 141. (C) Number of Aircraft Required — Sustained VTOL-Land Resupply of Two Committed Brigades, Normal Combat Intensity, Highland Region, 4 Hours Per Day Utilization. (U)




VTOL-Land
Hover-
Drop
VTOL-Land
Hover-
Drop
ventional
tical/Modular
400


2 Brigade Bases
Normal Combat Intensity
Number
Aircraft
Required
0
20
40
60
80
VTOL - Land
STOL - Land
Conventional
Vertical/Modular
0
100
200
300
400
Radius (Nautical Miles)

rmal
r Day

2

TABLE LIV (C)
POSSIBLE CRITERIA FOR DETERMINING THE SIZE OF THE AIRCRAFT COMPLEMENT BASED ON A CAPABILITY FOR SUSTAINED OR PEAK DAILY RESUPPLY OF TWO COMMITTED BRIGADES (U)

Combat Intensity	Temp/Alt (°F/Ft)	Number Aircraft Criteria[1]	Airland Delivery Mode Bn/Bgde	Radius Bn/Bgde (N Mi)	6 Bn Areas		2 Bgde Bases		2 Brigades	
					Conv	Vert/Mod	Conv	Vert/Mod	Conv	Vert/Mod
Normal	87/SL	U	VTOL/VTOL	200/150	22.0	19.7	25.2	22.8	47.2	42.4
	95/3000	A	VTOL/VTOL	200/150	16.2	14.2	18.7	16.7	34.9	30.9
Normal	83/2000	U	VTOL/VTOL	200/150	26.3	23.4	30.2	27.1	56.5	50.5
	83/2000	U	VTOL/VTOL	150/125	19.5	17.3	25.2	22.6	44.7	39.9
Maximum	83/2000	A	VTOL/VTOL	200/150	28.1	24.6	29.8	26.5	57.7	51.1
	83/2000	A	VTOL/VTOL	150/125	21.2	18.9	25.3	22.7	46.5	41.6
	83/2000	A	VTOL/VTOL	100/100	15.0	13.4	21.0	19.0	36.1	32.4
Maximum	83/2000	A	VTOL/STOL	200/150	28.1	24.6	14.6	15.4	42.7	40.0
	83/2000	A	VTOL/STOL	150/125	21.2	18.9	12.7	13.5	33.9	32.4
Normal	83/2000	U	VTOL/STOL	150/125	19.5	17.3	11.7	12.4	31.2	29.7

[1] "U" refers to basing the number of aircraft on a 4 hours/day utilization per complement aircraft; "A" refers to basing the number of aircraft on a 12-hour operating day and a 75% availability.

TABLE LV (C)
AIRCRAFT COMPLEMENT REQUIRED TO COMPLETE SELECTED
REPRESENTATIVE DEPLOYMENT MISSIONS (U)

Criteria	Flight Profile	Radius (Nautical Miles)	Number of Aircraft Required to Transport Unit: Bgde Base C	Bgde Base V/M	Inf Bn C	Inf Bn V/M	Engr Pltn C	Engr Pltn V/M	How Btry C	How Btry V/M
1 Lift*	VTOL/VTOL	25	-	-	-		38	43	11	11
	STOL/VTOL	75	-	-	56	59	35	38	11	11
	STOL/VTOL	150	268	300	59	64	38	44	11	12
	STOL/STOL	300	209	210	50	50	32	32	11	11
1 Day**	STOL/VTOL	75	-	-	4.7	4.9	4.0	4.3	0.9	0.9
	STOL/VTOL	150	35.1	39.2	7.7	8.4	6.7	7.9	1.4	1.6
	STOL/STOL	300	45.5	45.9	10.7	10.7	9.3	9.3	2.3	2.3

*Based on 75% availability; 83°F/2000 Ft.
**Based on 75% availability and 12-hour operating day; 83°F/2000 Ft.

TABLE LVI (C)

FIXED OPERATING COSTS FOR PEACETIME AND WARTIME OPERATIONS (U)

		Per Delivery System			
		Peacetime		Wartime	
	Per Man	Conventional	Vertical/Modular	Conventional	Vertical/Modular
Annual Cost ($/Year)					
Pilots	11,100	44,100	44,100	44,100	44,100
Crew Chiefs	5,700	11,400	11,400	11,400	11,400
Maintenance Personnel	4,500	175,500	184,500	220,500	229,500
Support Personnel	3,000	27,000	27,000	33,000	33,000
Overhaul Personnel	7,200	15,100	15,100	15,100	15,100
Total	-	273,100	282,200	324,100	333,100
Number Delivery Systems	-	57	51	57	51
Total Fixed Operating Cost Per Month ($/Month)	-	1,297,200	1,199,400	1,539,600	1,415,800

TABLE LVII (C)
PEACETIME FIXED AND VARIABLE OPERATING COST PER MONTH (U)

Cost Element	Cost Per Month: Conventional	Cost Per Month: Vertical/Modular
Personnel (80% Manning)[1]	1, 297, 200	1, 199, 400
Petroleum, Oil, and Lubricants (POL)[2]	114, 000	102, 000
Recurring Spares[3]	136, 800	128, 520
Lost Aircraft (Accidents)[4]	273, 600	255. 000
Total	1 821, 600	1, 684, 920

[1] 80% values in Table XLI; 57 conventional delivery system aircraft and 51 vertical/modular delivery system aircraft.

[2] 40 flight hours per aircraft per month; $50 per flight hour for POL.

[3] $60 and $63 per flight hour for conventional and vertical/modular systems, respectively.

[4] Accidential losses $120 and $125 per flight hour for the conventional and the vertical/modular system, respectively.

TABLE LVIII (C)
WARTIME FIXED AND VARIABLE OPERATING COSTS PER MONTH (U)

	87°F/Sea Level		83°F/2000 Ft	
	Conventional	Vertical/Modular	Conventional	Vertical/Modular
Fixed Operating Cost/Month[1]	1,539,600	1,415,800	1,539,600	1,415,800
Variable Operating Cost/Month				
Resupply	1,064,378	1,033,314	1,145,972	1,093,474
Deployment	780,057	847,608	843,938	954,082
Resupply and Deployment	1,844,435	1,880,922	1,989,910	2,047,556
Total Operating Cost/Month				
Resupply Only	2,603,978	2,449,114	2,685,572	2,509,274
Resupply Plus Deployment	3,384,035	3,296,722	3,529,510	3,463,356

[1] 100% manning from Table XLI for 57 and 51 aircraft for the conventional and vertical/modular delivery system, respectively.

TABLE LIX (C)
10-YEAR TOTAL SYSTEM COST (U)

	Number Aircraft Based on Resupply Criterion		Equal Number Aircraft
	Conventional ($1000)	Vertical/Modular ($1000)	Vertical/Modular ($1000)
RDTE Cost[1]	7,581	7,599	8,493
Investment Cost[1]	149,984	139,806	156,254
Operating Cost Per Month			
Wartime[2]			
87°/SL	2,604/3,384	2,449/3,297	2,616/3,464
83°/2000 Ft	2,686/3,530	2,509/3,463	2,676/3,630
Peacetime	1,822	1,685	1,883
10-Year Total System Cost			
100% Peacetime	376,205	349,605	390,707
100% Wartime			
Resupply Only			
87°F/SL	470,045	441,285	478,667
83°F/2000 Ft	479,885	448,485	485,867
Resupply Plus Deployment			
87°F/SL	563,645	543,045	580,427
83°F/2000 Ft	581,165	562,965	600,347

[1] 57 conventional and 51 and 57 vertical/modular delivery systems.

[2] Resupply only/resupply plus deployment.

TABLE LX (C)
FIXED AND VARIABLE PARTS OF 10-YEAR TOTAL SYSTEM COST (U)

	Delivery System	Number Aircraft	RDTE and Investment Cost (Millions)	Fixed Operating Cost (Millions)	Total Fixed Cost (Millions)	Variable Operating Cost (Millions)	Total System Cost (Millions)
100-Percent Peacetime	Conventional	57	157.6	155.7	313.3	62.9	376.2
	Vert/Mod	51	147.4	143.9	291.3	58.3	349.6
	Vert/Mod	57	164.7	160.8	325.5	65.2	390.7
100-Percent Wartime							
Resupply Only (87°F/SL)	Conventional	57	157.6	184.7	342.3	127.7	470.0
	Vert/Mod	51	147.4	169.9	317.3	124.1	441.3
	Vert/Mod	57	164.7	189.8	354.5	124.1	478.7
Resupply Plus Deployment (87°F/SL)	Conventional	57	157.6	184.7	342.3	221.3	563.6
	Vert/Mod	51	147.4	169.9	317.3	225.8	543.0
	Vert/Mod	57	164.7	189.8	354.5	225.8	580.4
Resupply Only (83°F/2000 Ft)	Conventional	57	157.6	184.7	342.3	137.6	479.9
	Vert/Mod	51	147.4	169.9	317.3	131.3	448.5
	Vert/Mod	57	164.7	189.8	354.5	131.3	485.9
Resupply Plus Deployment (83°F/2000Ft)	Conventional	57	157.6	184.7	342.3	238.9	581.2
	Vert/Mod	51	147.4	169.9	317.3	245.7	563.0
	Vert/Mod	57	164.7	189.8	354.5	245.7	600.3

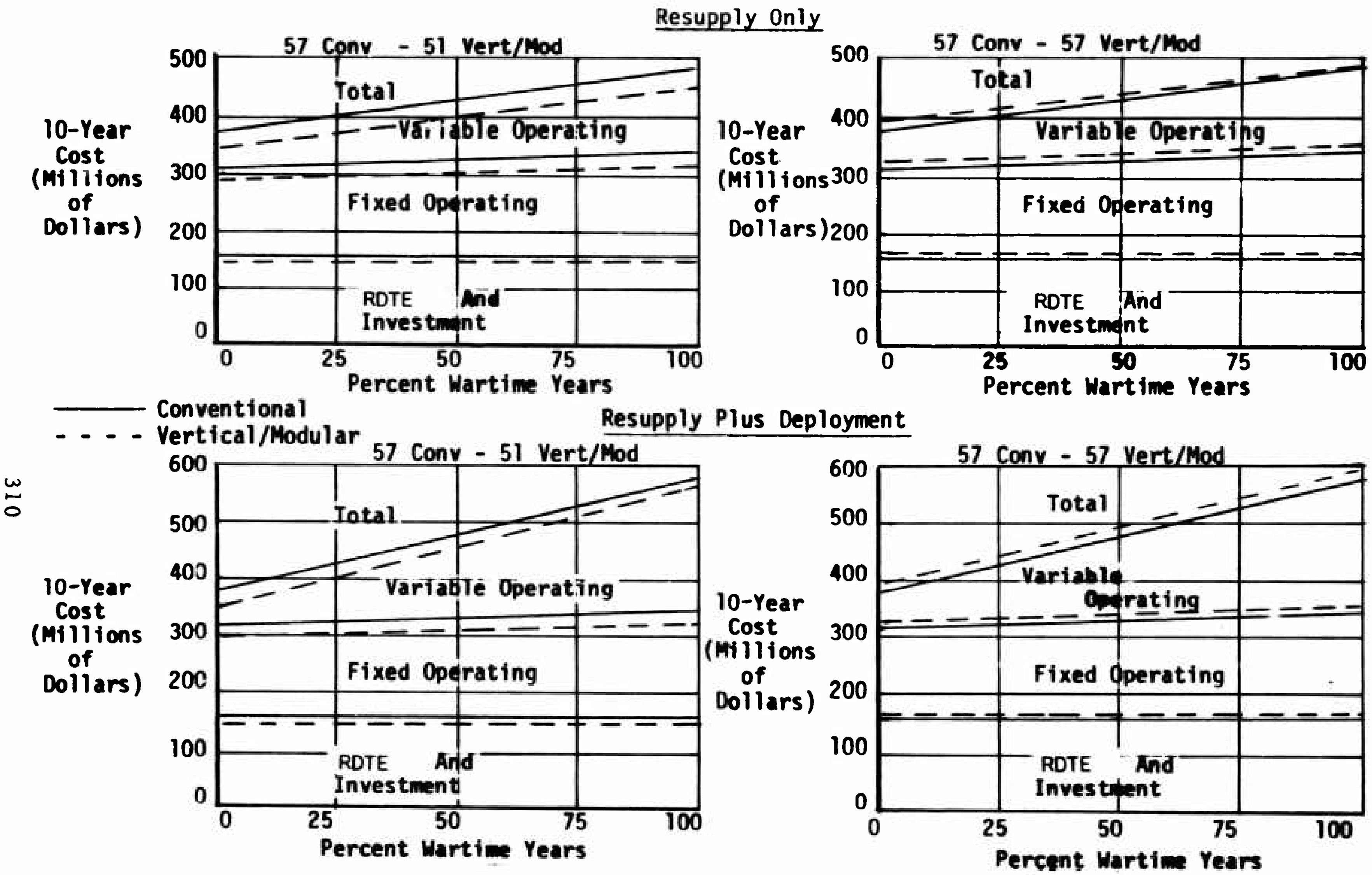


Figure 142. (C) 10-Year Total System Cost Versus Percent of System Life Which is Spent in Wartime Operations; Highland Region. (U)

becomes less competitive with the conventional system, especially if these deployments involve VTOL takeoffs or landings. The converse is true for resupply operations, especially if few airfields are available.

(U) In light of the qualitative advantages of the vertical/modular system, and of the conservative assumptions discussed at the end of the last chapter, the vertical/modular system is at a minimum cost-competitive with the conventional system so long as their primary mission is direct resupply of forward area units.

TABLE LXI (C)

10-YEAR TOTAL SYSTEM COST DIFFERENCES AS A PERCENTAGE RELATIVE TO THE VERTICAL/ MODULAR SYSTEM COSTS* (U)

Criteria Determining Number of Aircraft	Peace-time Training	Wartime Operations: Resupply Only		Wartime Operations: Resupply Plus Deployment	
		87°F/SL	83°F/ 2000 Ft	87°F/SL	83°F/ 2000 Ft
Resupply (57 Conv and 51 Vert/Mod)	+7.6	+6.5	+7.0	+3.8	+3.2
Illustrative Case (57 Each)	-3.7	-1.8	-1.2	-2.9	-3.2

*Positive (+) values indicate conventional system is more expensive for the mix of missions assumed.

(U) CONCLUSIONS

The conclusions drawn from this study are divided into those associated with the design feasibility and those associated with the comparative evaluation of the proposed delivery system.

Design Conclusions

The installation of a vertical/modular delivery system in an aircraft the size of the XC-142A can be accomplished for a weight penalty to the airframe of approximately 1500 pounds above the basic airframe weight. This is approximately 750 pounds more than would be required to equip the aircraft with a conventional aerial delivery system.

One problem associated with the system installation is that the torsional rigidity of the aircraft fuselage is reduced due to the bottom openings. Although a flutter analysis of the XC-142A was not available to the contractor, the torsional rigidity does not appear to be critical.

The mechanical design of the system to drop cargo can be accomplished using presently available engineering principles.

The aircraft response to the dropping of loads can be maintained within the allowable values of the stability and control parameters by utilizing an airdrop sequential control system.

The payload/radius performance of an XC-142A type aircraft can be considerably improved for resupply missions which require the aircraft to use the VTOL flight mode if the vertical/modular system is installed. The aircraft would have the capability to change weight in case of an emergency in the VTOL flight mode by jettisoning cargo. This means the T/W ratio requirement for VTOL landing can be reduced. The gain in payload shown in this study was based on reducing the T/W ratio from 1.10 to 1.05. This is conservative, but applies only when the aircraft is both (1) carrying cargo which may be discharged if an engine is lost, and (2) using a vertical takeoff and/or landing.

Comparative Evaluation Conclusions

The main conclusions of the evaluation are:

1. The vertical/modular system is less costly and more effective for battalion area resupply, and also for brigade base resupply when no airfield is available. This study assumed equal loss rates for both systems for a given delivery mode. Detailed vulnerability analysis should show these cost differences to be larger.

2. The major cost and effectiveness advantages of the vertical/modular delivery system depend on being able to reduce the thrust-to-weight ratio.

3. Both the packing and rigging required and the cargo damaged are less for the vertical/modular system in the airdrop and hover-drop delivery modes.

4. The selective cargo discharge capability of the vertical/modular system is technically feasible and most desirable, but cannot be started as a firm requirement for forward area resupply.

5. The vertical/modular delivery system shows a cost penalty in the performance of deployment missions compared to the conventional system. Since troops and vehicles cannot be jettisoned if an engine is lost, both delivery systems operate at a 1.10 thrust-to-weight ratio on deployment missions. The vertical/modular system weight penalty results in the system's requiring more cycles than the conventional system. As a result of the additional cycles required, the vertical/modular system is less efficient for deployment operations.

6. Cost and effectiveness differences are small and inconclusive when mixes of resupply and deployment missions in support of both battalion area and brigade base units are considered. Resupply operations, especially when no airfields are available, favor the vertical/modular system. Deployment operations, especially when no airfields are available, favor the conventional system. The overall cost advantage of the vertical/modular delivery system is marginal.

7. Cost is prohibitive and effectiveness questionable for airdrop from a V/STOL aircraft. This is true even without considering the pipeline stocks and specially trained personnel required to maintain an airdrop capability.

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(U) GLOSSARY

Accuracy Loss	The cargo that falls outside the geographic area controlled by the military unit and is not available for use by that unit.
Aerial	A modifier used to indicate transportation involving an airborne vehicle.
Aircraft Complement	Total number of XC-142 delivery systems physically located at logistics support base, exclusive of aircraft in major overhaul.
Aircraft Utilized	Total number of XC-142 delivery systems required to complete a mission or combination of missions based on either operating hours per day or utilization per day.
Airdrop	A delivery mode in which cargo is discharged at an altitude of between 500 and 1,500 feet with the descent of that cargo retarded by a parachute.
Airfield	A geographic area of sufficient size and smoothness to permit takeoffs and landings with a ground run.
Airframe	The complete aircraft less engines, avionics and other equipment.
Airland	A modifier used to indicate that the aircraft physically lands on the ground, either vertically or with a ground run.
Air Line of Communications (ALOC)	Transportation of men, supplies, and equipment by air.
Attrition	The loss of an aircraft due to accidents or enemy fire, where the aircraft cannot be repaired and returned to service.
Available Aircraft	The average quantity of delivery systems available for use on a mission, equal to or less than the aircraft complement.
Battalion Area	Forwardmost geographic area within which contact between division units and enemy forces is most likely to occur.
Brigade Area	Geographic area encompassing a brigade base and the battalion area under the command of the brigade base.

Brigade Base	Intermediate base between division base and battalion area from which operations in battalion area are directed and supported.
Cargo	Anything carried by the aircraft as payload.
Cargo Dispatched	The sum of (1) 99.9 percent of the cargo required by a military unit to support combat operations plus (2) the incremental cargo required to compensate for cargo lost due to aircraft attrition, delivery system accuracy, and cargo impact damage.
Cargo Handling System	Cargo handling equipment installed in the aircraft to aid in the loading, unloading, and restraint of the cargo.
Cargo Handling Time	The sum of the time required to load, restrain, and unload cargo and to verify weight and balance.
Cargo Required or Cargo Requested	The tons of cargo requested by a military unit to support combat operations.
Combat Intensity	The relative amount of contact between friendly and enemy forces.
Conventional	A modifier used to indicate a cargo handling system which has the capability to discharge cargo out the aft doors of an aircraft either in flight or on the ground.
Cost Allocation	Assignment of total system cost elements as a function of flight hours, operating days, tons cargo transported or cycles.
Cost Category	Major breakdown of total system costs into (1) research development, test and evaluation, (2) investment, and (3) operating costs.
Cost Element	An identifiable component of a cost category.
Cost Per Aircraft Per Day	Sum of those cost elements that are fixed with the aircraft complement and allocated on a per day basis.
Cost Per Cycle	Sum of those cost elements that are variable and primarily a function of cycles and allocated on a per cycle basis.

Cost Per Flight Hour	Sum of those cost elements that are variable and primarily a function of flight hours and allocated on a per flight hour basis.
Cost Per Ton Cargo	Sum of those cost elements that are variable and primarily a function of tons of cargo transported and allocated on a per ton cargo basis.
Crew	Total flying personnel required to deliver cargo.
Cushioning	Paper honeycomb used to absorb shock when cargo impacts with ground.
Cycle	One round trip of an aircraft from point of origin to destination and return to point of origin, regardless of the number of stops made at the destination.
Cycle Time	Sum of ground time plus flight time.
Delivery Mode	Method of cargo delivery specified by the speed and altitude of the aircraft at the instant the cargo is discharged, the means by which the cargo is discharged from the aircraft, and the means by which the cargo reaches the ground.
Delivery Site	The specific geographic location where the cargo is intended to reach the ground.
Delivery System	Aircraft including cargo handling system.
Deployment	Movement of military units from one geographic location to another.
Descent Parachute	Parachute used to retard the rate of cargo descent in airdrop.
Destination	The general geographic area to which cargo is to be delivered.
Division Area	Geographic area in which division units are deployed.
Division Base	Base from which division operations are directed and supported.
Downed Aircraft	Aircraft unable to complete a mission due to accidents or enemy fire. Some of these aircraft may be repairable.
Drop Zone	The defined geographic area within which airdrop cargo must land to be recovered by the intended user.

Expected Utilization	Anticipated annual flight hours per aircraft used in planning delivery system requirements.
Extraction Parachute	A parachute used to extract cargo through the aft doors of an aircraft equipped with a conventional cargo handling system.
Fixed Cost	The sum of the cost elements of total system cost that are fixed for a given aircraft complement and expected utilization.
Fixed Operating Cost	The sum of the operating cost elements of total system cost that are fixed for a given aircraft complement and expected utilization.
Flight Time	That part of cycle time during which engines are running, including the time to taxi, take off, climb, cruise and descend, land or drop cargo, and fly between drops for multiple drop cases.
Flyaway Cost	Production cost of airframe, engines, avionics, and other equipment including the cargo handling system.
Ground Support Equipment	Ground equipment peculiar to and required for the maintenance and operation of the delivery system.
Ground Time	That part of cycle time during which engines are not running, including the time to fuel the aircraft, load and restrain the cargo, release restraint and unload cargo, and verify weight and balance.
Hover	To remain suspended above one location at or near zero velocity.
Hover-Drop	A delivery mode in which cargo is discharged while the aircraft is hovering at a very low altitude (below 15 feet) and at near-zero forward velocity.
Incremental Cycles	Additional cycles required to compensate for cargo lost due to aircraft attrition, delivery system accuracy, and cargo impact damage.
Initial Spares and Spare Parts	The maintenance materials necessary to establish the required inventory in the Army supply system and to support the aircraft during the first year of operation. This includes airframe, cargo delivery system, avionics, engine, and other equipment spares and spare parts.
Investment Cost	The cost of procuring the delivery system, ground support equipment, and initial spares and spare parts that are required to integrate the aircraft system into the operational inventory.

Landing Zone	An area suitable for vertical, but not STOL, landing of an XC-142A.
Logistics Support Base	Base at which resupply cargo for division area originates and is stockpiled.
Lost Aircraft	Aircraft downed by accidents or enemy fire that are not repairable.
Lost Cargo	Cargo dispatched that does not reach the user due to parachute failures, delivery system accuracy, and cargo impact damage.
Major Deployment	An operation involving the movement of a division combat element which includes moving the division base.
Maximum Availability	The maximum percentage of the aircraft complement that may be made available for a mission.
Maximum Operating Day	The maximum hours per day during which aerial operations are assumed tenable.
Maximum Payload	Weight limited payload of an aircraft at a given radius.
Maximum Utilization	Assumed maximum number of flight hours per day per aircraft during periods of peak demand.
Military Unit	Organizational element of a division.
Minimum Cycles Per Day	Number of cycles required to deliver 100 percent of cargo requirements assuming no cargo loss.
Mission	Part of an operation in support of a specific military unit specified by radius, combat intensity, and cargo characteristics.
Mission Cost	That variable part of total system cc -t which accrues during the performance of a defined mission.
Operating Cost	Recurring expenditures required for the operation and maintenance of the delivery system after it is operational.
Operating Day	The average hours per day during which aerial operations are conducted.
Operation	General class of air transport missions including major deployments, tactical redeployments, resupply, wartime lull, and peacetime training.

Operational Concept	The missions, routes, cargo, distances, delivery modes, and other environmental parameters which define the manner in which an aerial delivery system is employed in military operations.
Origin	Beginning and terminal point of a cycle.
Outbound Flight	The segment of a cycle composed of the trip from origin to destination.
Overhauls	Accomplishment of major rework and repair on delivery systems.
Packaging	Material used to contain cargo in a given geometric shape.
Payload Degradation	The decrease in maximum payload due to an increase in the operating weight empty of an aircraft as a result of the addition of a cargo handling system to an aircraft.
Peculiar Cargo Costs	A collective term used to designate the costs associated with cargo delivery including packaging, parachutes, rigging, pallets, and cushioning.
Personnel Pay and Allowances	The cost to the government for military personnel including basic pay and all allowances.
POL	Petroleum, oil and lubricants.
Recurring Spares and Spare Parts	Maintenance materials necessary to operate and maintain the delivery system.
Refueling Time	Time required to put sufficient fuel in aircraft to complete one cycle.
Research, Development, Test and Evaluation (RDTE) Costs	The cost of developing, designing, and testing a new aircraft.
Reserve Brigade	A brigade not committed to combat.
Resupply	The operation of replenishing materials consumed by military units.
Retrograde Cargo	Cargo carried on return flight from destination to origin.

Return Flight	The segment of a cycle composed of the trip from destination to origin.
Route	Ground path followed by aircraft during a military operation.
Selectivity	A term used to indicate the capability to discharge all or part of an aircraft cargo load independent of the order in which it was loaded.
STOL-Land	A delivery mode in which the aircraft lands with a ground run and discharges cargo through the aft doors.
Support Aircraft	The difference between available aircraft and aircraft utilized.
Support Personnel	Those personnel required to operate an aircraft delivery system in addition to maintenance, cargo handling, and crew personnel.
Tactical Redeployment	An operation involving the movement of a division combat element without moving the division base.
Total Cargo	The difference between cargo dispatched and the cargo reaching the intended user (resulting from parachute failures, delivery system accuracy, and cargo impact damage).
Total Cycle Hours Per Day	Product of cycle hours per aircraft per day and number of aircraft utilized, or the product of total cycles per day and the flight hours plus ground hours per cycle.
Total System Cost	The cost of developing, procuring and operating a delivery system for an n-year period.
Unit	See military unit.
Utilization	The number of flight hours logged on an individual aircraft in a specified time period.
Vertical/ Modular	A modifier used to indicate a cargo handling system which has the capability to discharge cargo either vertically through the belly of an airborne aircraft or conventionally through the aft doors while on the ground.
Volume Limited	A modifier used to designate that the aircraft payload is less than maximum payloads due to size of cargo compartment.
VTOL-Land	A delivery mode in which the aircraft lands vertically and discharges cargo through the aft doors.

Vulnerability	The state in which an aircraft may be exposed to enemy fire.
XC-142A	The (tilt-wing, four-engine, turboprop) V/STOL aircraft used as a basis for this study.
Variable Operating Cost	The variable portion of total operating cost which would not accrue to the system if the aircraft did not perform a particular mission.

(C) APPENDIX I (U)

AIRMOBILE DIVISION AND CARGO DATA (U)

TABLE LXII (U)

AIRMOBILE DIVISION UNIT LOCATIONS ASSUMED FOR STUDY

			COMMITTED BRIGADE COMMAND (2 Per Division)			
	Division Area		Com. Bgde. Hq. Area (2 Per Division)		Battalion Area (3 Per Committed Bgde.)	
Function	Unit	Men	Unit (Per Bgde.)	Men	Unit (Per Bn.)	M[illegible]
Div. Command	Div. Hq. & Hq. Co.	155				
Bgde. Command			Bgde. Hq. & Hq. Co.*	213		
Inf. Battalion					Bn. Hq. & Hq. Co. Combat Supt. Co. Rifle Co. "A" Rifle Co. "B" Rifle Co. "C"	[illegible] [illegible] [illegible] [illegible] [illegible]
Military Police	Hq. & Hq. Co. Security Plt.	24 93	MP PLTN	31		
Eng'r. Bn.	Hq. & Hq. Co.	269	Combat Eng'r. Co. Hq.	12	Eng'r. Pltn.	[illegible]
Signal Bn.	Hq., Hq., & Sur. Co. Cmd. Ops. Co.	76 215	Fwd. Supt. Sec. Radio Supt. Sec.	6 9		
Artillery Aviation Btry.	Hq. & Hq. Btry. Hq., Flt. Ops., & Service Dir. Supt. Pltn. Hq. Gen. Supt. Pltn.*	154 51 2 18	Dir. Supt. Aviation Sec.* (With 105's)	8		
F. A. Bn. Aer. Art.	Hq., Hq. & Svc. Btry.* F. A. Bn. Aer. Art. Btry. Hq., Flt. Ops., Comm., Svc, Maint. & Svc. 3 Aer. Art. Pltn. Hq. 6 Aer. Art. Sec.*	87 63 9 33	F. A. Bn. Aer. Art. Btry.** Hq., Flt. Ops., Comm., Svc., Maint. & Svc. 3 Aer. Art. Pltn. Hq. 6 Aer. Art. Sections*	63 9 33		
F. A. Bn. 105 mm (Towed)			F. A. Bn. 105 mm Hq., Hq. & Svc. Btry.	132	F. A. Btry. 105 mm	[illegible]
Aviation Group	Hq. & Hq. Co. Gen. Supt. Avn. Co.* Aslt. Supt. Hel. Bn. Hq.* 3 Aslt. Supt. Hel. Co.*	223 194 89 432	Aslt. Hel. Bn. Hq. & Hq. Co.* ** Aslt. Hel. Bn. Aer. Wpns. Co.* 3 Aslt. Hel. Bn. Aslt. Hel. Co.*	95 93 339		
Cavalry Sqdn.	Hq. & Hq. Trp.* Cav. Trp. (Ground) Air Cav. Trp. "A"* Air Cav. Trp. "B"* Air Cav. Trp. "C"*	182 132 152 152 152				
Support Command Supply Bn.	Hq., Hq. Co., Adm., & Band Sup. Bn. Hq. & Hq. Svc. Sup. Bn., Sup. Co. (-3 Pltn.) Sup. Bn. QM. Aer. Eq. Supt. Co.	542 140 128 104	Sup. Bn. Fwd. Supt. Pltn.	36		
Trans. A/C Maint. & Supply Bn.	Hq. & Hq. Co.* 4 Trans. A/C M. & S. Co.*	104 1324				
Medical Bn.	Hq. & Supt. Co.*	189	Med. Co.	74		
Maint. Bn.	Hq. & Maint. Supt. Co.	205	Fwd. Supt. Det.	43		
		5693		1196		[illegible]

* Asterisk denotes unit with aircraft.

** Depending upon the terrain and tactical situation, the helicopters of the F. A. Bn. Aerial Artillery Batteries and of the assault Helicopter Battalions may return to the Division Base at night for security, even though the unit is basically resupplied at the committed brigade base.

D BRIGADE COMMAND (2 Per Division)				Reserve Brigade Command (1 Per Division)				
ea		Battalion Area						
		(3 Per Committed Bgde.)		Res. Brigade H.Q. Area		Battalion (2 Per Res. Bgde.)		
	Men	Unit (Per Bn.)	Men	Unit (Per Bgde.)	Men	Unit (Per Bn.)	Men	Notes
	213			Bgde. Hq. & Hq. Co.*	213			
		Bn. Hq. & Hq. Co.	134			Bn. Hq. & Hq. Co.	134	
		Combat Supt. Co.	123			Combat Supt. Co.	123	
		Rifle Co. "A"	170			Rifle Co. "A"	170	
		Rifle Co. "B"	170			Rifle Co. "B"	170	
		Rifle Co. "C"	170			Rifle Co. "C"	170	
	31			MP PLTN	31			
	12	Eng'r. Pltn.	35	Combat Eng'r. Co. Hq.	12			
				3 Eng'r. Pltn.	105			
	6			Fwd. Supt. Sec.	6			
	9			Radio Supt. Sec.	9			
	8			Dir. Supt. Aviation Sec.* (With 105's)	8			
	63							
	9							
	33							
	132	F. A. Btry. 105 mm	89	F. A. Bn. 105 mm	89			
				Hq., Hq. & Svc. Btry.	132			
				3 F. A. Btry. 105 mm	267			
**	95			(No Aslt. Hel. Bn.)				
*	93							
*	339							
	36			Sup. Bn. Fwd. Supt. Pltn.	36			
	74			Med. Co.	74			
	43			Fwd. Supt. Det.	43			
	1196		891		936		767	

assault Helicopter Battalions may return to

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TABLE LXIII (U)

AIRMOBILE DIVISION AIRCRAFT, WEAPON SYSTEMS, AND LOCATIONS ASSUMED FOR STUDY

	Number of Units	Aircraft				
		OH	UH-1B		UH-1D	
Total Division		93	111		176	
Aviation Battery (of Div. Art.)						
Dir. Supt. Pltn. HO	1					
Dir. Supt. Pltn. Avn. Sec.	1	4	0		0	
Dir. Supt. Pltn. Avn. Sec.	1	4	0		0	
Dir. Supt. Pltn. Avn. Sec.	1	4	0		0	
General Supt. Pltn.	1	4	4	(XM-16)	0	
FA Bn. Aer. Art. HQ	1	0	3	(XM-16)	0	
Aerial Art. Battery	1	0	12	(XM-3)	0	
Aerial Art. Battery	1	0	12	(XM-3)	0	
Aerial Art. Battery	1	0	12	(XM-3)	0	
Sub Total	-	16 (XM-7)	43		0	
Av. Grp	1					
Gen. Supt. Avn. Co.	1	10	6		4	
Aslt. Hel. Bn.	1	3	12		60	
Aslt. Hel. Bn.	1	3	12		60	
Aslt. Supt. Hel. Bn.	1	3	0		0	
Sub Total	-	19 (XM-7)	30	(XM-16)	124	(XM-23)
Bgde Hq. & Hq. Co.	1	8	0		5	
Bgde Hq. & Hq. Co.	1	8	0		5	
Bgde Hq. & Hq. Co.	1	8	0		5	
Sub Total	-	24 (XM-7)	0		15	(XM-23)
Cav. Sqdn. Sub Total	1	30 (XM-7)	38	(XM-16)	20	(XM-23)
Support Command	1					
Trans. A/C Maint. & Sup. Bn. HO	1	0	0		1	(XM-23)
Trans. A/C Maint. & Sup. Co.	1	1	0		1	(XM-23)
Trans. A/C Maint. & Sup. Co.	1	1	0		1	(XM-23)
Trans. A/C Maint. & Sup. Co.	1	1	0		1	(XM-23)
Trans. A/C Maint. & Sup. Co.	1	1	0		1	(XM-23)
Med. Bn. HQ	1	0	0		12	(None)
Sub Total	-	4 (XM-7)	0		17	
Total Division Aircraft 434 (428 are helicopters)						

Aircraft							Assumed Location		
UH-1B		UH-1D		OV-1B	CH-47	TOTAL	DIV.	BDGE.	
111		176		6	48	434	-	-	
							X		
0		0		0	0	4		X	With 105's
0		0		0	0	4		X	
0		0		0	0	4		X	
4	(XM-16)	0		0	0	8	X		
3		0		0	0	3	X		
12		0		0	0	12	X		
12	(XM-3)	0		0	0	12		X	
12		0		0	0	12		X	
43		0		0	0	59			
6		4		6	0	26	X		
12		60		0	0	75		X	
12		60		0	0	75		X	
0		0		0	48 (XM-24)	51	X		
30	(XM-16)	124	(XM-23)	6	48	227			
0		5		0	0	13		X	
0		5		0	0	13		X	
0		5		0	0	13		X	
0		15	(XM-23)	0	0	39			
38	(XM-16)	20	(XM-23)	0	0	88	X		
0		1		0	0	1	X		
0		1		0	0	2	X		
0		1	(XM-23)	0	0	2	X		
0		1		0	0	2	X		
0		1		0	0	2	X		
0		12	(None)	0	0	12	X		
0		17		0	0	21			

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TABLE LXIV (U)

RECAP OF COMMITTED BRIGADE VEHICLES AND MEN

Line Item No.	Description	BGD HQ	Aslt Helic Bn	Comb Eng Co HQ	HQ & Serv Bat FA	Med Co	Aer Art Bat	Fwd Supt Plat Supt Bn	Fwd Supt Sect Sig Bn	Fwd Supt Det Maint Bn	MP Plat, MP Co	Direct Supt Avn Sect Div Art	Cmtd Bn (3)	Total
	Men	213	527	12	132	74	105	36	15	43	31	8	2673	3869
	Vehicles													
461793	1/4 T Trk 106 mm												24	24
461790	1/4 T Trk	17	20	1	14	3	3	3	5	2	7		24	99
457110	1/4 T Trlr	16	18	1	14	3	3	3	5	2	3			68
459832	1/4 T Amb		1											1
461206	1/2 T Truck	6	12		3								60	81
460050	3/4 T Truck	2	43		2		5							52
460080	3/4 T Truck	6			9		1			3			6	25
457190	3/4 T Trlr	7	43	1	2		4			1				58
460110	2 1/2 T Truck*		12		2		2							16
457220	1 1/2 T Trlr*		11		1		1							13
457495	1 1/2 T W. Trlr*		1		1		1							3
461329	2 1/2 T Fuel Trk*	1	4				1							6
948910	Scooter		6											6
947016	3/4 T Dump Trk			1									73	73
405215	Lt. Weap. Carrier									4				4
942825	3/4 T Trk w/Wrecker									1				1
732701	UH-1B*		12				12							24
732703	UH-1D*	5	60											65
973245	LOH*	8	3									4		15
418618	105 mm How.												18	18

* Not transported in XC-142.

TABLE LXV (U)

RECAP OF COMMITTED BRIGADE WEAPONS

Line Item No.	Unit Weapons Description	BGD HQ	Aslt Helic Bn	Comb Eng Co HQ	HQ & Serv Bat FA Bn	Med Co	Aer Art Bat	Fwd Supt Plat Supt Bn	Fwd Supt Sect Sig Bn	Fwd Supt Det Maint Bn	MP Plat, MP Co	Direct Supt Avn Sect Div Art	Cmtd Bn (3)	Total
420670	40 mm Gren. Launc.	15	24		3				2		4		276	325
422585	Lt. Mach. Gun 7.62 mm	6			6		7	1		9	1		90	128
429280	Pistol Cal. .45	42	6	1	24	7	5		2	1	5		811	904
435840	Pistol Cal. .38	32	251				36					8		327
944695	Rifle 5.56 mm	135	243	11	108	66	64	36	13	42	30		1980	2728
400300	Helic. Guid. Miss. SS-11B						4							4
420800	3.5 in Rocket Launch.							1		1				2
435890	Rifle 90 mm												54	54
423620	Mortar 81 mm												39	39
940065	Helic. Arm. XM-23	5	60											65
940067	Helic. Arm. XM-7	8	3									4		15
948927	Weap. Sup. Syst. XM-16		12											12
94007	Helic. Arm. 2.75 Rock XM-3						12							12
435950	Rifle 106 mm												24	24
418318	Howitzer 105 mm												18	18

TABLE LXVI (U)

RECAP OF COMMITTED BATTALION (1) VEHICLES AND MEN

UNIT	Inf Bn Hq & Hq Co	Rifle Co(3)	105 How Btry	Engr Pltn	Cmbt Supt	TOTAL
Men	134	510	89	35	123	891
Equipment						
460080 3/4 T Truck	2					2
461206 1/2 T Truck Plat.	8	6	1		5	20
461790 1/4 T Truck Jeep	4		2	1	1	8
947016 3/4 T Dump Truck				24		24
461793 1/4 T Truck (106 mm)					8	8
418318 105 mm Howitzer			6			6

TABLE LXVII (U)

RECAP OF COMMITTED BATTALION (1) WEAPONS

UNIT WEAPONS Line Item No.	Description	Inf Bn Hq & Hq Co	Rifle Co(3)	105 How Btry	Engr Pltn	Cmbt Supt	TOTAL
420670	40 mm Gren. Launcher	8	72	3	3	6	92
423630	Mortar 81 mm		9			4	13
429280	Pistol Cal. 45	39	165	4	6	23	237
435950	Rifle 106 mm					8	8
418318	Howitzer 105 mm			6			6
435890	Rifle 90 mm		18				18
944695	Rifle 5.56 mm	95	345	85	35	100	660
422585	Lt. Mach. Gun 7.62 mm	2	18	6	4		30

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TABLE LXVIII (U)

VEHICLE FUEL CONSUMPTION RATES PER VEHICLE PER DAY

Line Item No.	Vehicle Description	FM 101-10 Pol Consumption Fuel (Gal/100 sm)	Oil (Gal/100 sm)	Lubricants (Lb/100 sm)	Oil & Lubricants (Lb/Gal Fuel)	Type Fuel
461790	1/4 Ton Truck	7.1	.2	.4	.27	MoGa
461793	1/4 Ton 106 mm Carrier					
459832	1/4 Ton Amb. F. L. (4x4)	7.1	.3	.3	.36	MoGa
*948910	Scooter	2	.2	.2	.85	MoGa
461206	1/2 Ton Platform Truck (4x4 Mech. Mule Cargo)	6.7	.2	.4	.28	MoGa
460050	3/4 Ton Cargo Truck (4x4)	12	.2	.6	.18	MoGa
460080	3/4 Ton Cargo Truck (4x4 w/Wn)	12	.2	.6	.18	MoGa
*947016	3/4 Ton Dump Truck (4x4 1 cu. yd. cap.)	12	.2	.6	.18	MoGa
*942825	3/4 Ton Truck w/Wrecker (4x4 w/wkr ket)	12	.2	.6	.18	MoGa
460110	2-1/2 Ton Truck (6x6 LWB)	20	.4	1.2	.21	MoGa
461329	2-1/2 Fuel Truck (6x6 w/Wn)	20	.4	1.2	.21	MoGa
405215	Lt. Weapon Carrier Inf. (1/2 Ton 4x4); 1/2 Ton Platform Truck (4x4 Mech. Mule Cargo)	6.7 (Gal/hr)	.2 (Gal/hr)	.4 (Lb/hr)	.28	MoGa
732701	UH-1B Helicopter	57	.37	-	.15	JP-4
732703	UH-1D Helicopter	73	.37	-	.15	JP-4
*973245	OH-6A Helicopter	20	.20	-	.10	JP-4
	Generator Approximation	1-3	-	-	-	MoGa

* Developmental Item

1. FM-101-10-1, pg. 5-24 through 5.26
2. Trucks: 83% available; 4 short hauls of 15 miles one way each at 10 miles per hour (poor roads) for tota 100 miles per day assumed for battalion area normal and maximum combat intensity respectively; 100 a above are per assigned vehicle and include an adjustment for vehicle availability.
3. Helicopters: 67% available on sustained basis, about 90% available for periods of less than 6 days by ho holding all aircraft down 58 hours (Pg. 316 of Rucker Report).
4. Oil Assumed 7.5 lb/gallon.

Y

onsumption				Fuel Consumption per Assigned Vehicle (Availability Factor is Included)			
bricants /100 sm)	Oil & Lubricants (Lb/Gal Fuel)	Type Fuel	Tank Capacity (Gal)	Committed Brigade Base Normal	Committed Brigade Base Maximum	Committed Battalion Area Normal	Committed Battalion Area Maximum
.4	.27	MoGas	17	7.1	10.6	4.3	7.1
.3	.36	MoGas	20	7.1	10.6	-	-
.2	.85	MoGas	2	2	3	1.2	2.0
.4	.28	MoGas	8	6.7	10.0	4.0	6.7
.6	.18	MoGas	24	12	18	-	-
.6	.18	MoGas	24	12	18	7.2	12
.6	.18	MoGas	24	12	18	7.2	12
.6	.18	MoGas	24	12	18	-	-
1.2	.21	MoGas	50	20	30	-	-
1.2	.21	MoGas	56	20	30	-	-
.4 (Lb/hr)	.28	MoGas	8	6.7	10	4.0	6.7
-	.15	JP-4	155	228	456	-	-
-	.15	JP-4	220	292	584	-	-
-	.10	JP-4	59	80	160	6	10
-	-	MoGas	-	20	36		

miles per hour (poor roads) for total of 120 Mi. per day. (FM-101-10-1, Pgs. 7-10 and 7-20); 60 and
ombat intensity respectively; 100 and 150 for the corresponding Brigade Base intensities. Mileages
availability.
r periods of less than 6 days by holding aircraft down 36 hours prior to operation or to 100% by

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TABLE LXIX (C)

AMMUNITION EXPENDITURE RATES PER WEAPON PER DAY (U)

Line Item Number	Weapon Description	Firing Rate: Maximum (Rnd/Min Unless Noted)	Firing Rate: Sustained (Rnd/Min Unless Noted)	Firing Rate: Effective (Rnd/Min Unless Noted)	Rucker Training Manual (1966) (Rnd/Loading)	CSSG Letter From RAC Air Assault Report (1963) (Lb/Rnd)	CSSG Letter From RAC Air Assault Report (1963) (Rnd/D
418318	105 mm Howitzer (M102)	10	3	-	-	60.	45
420800	3.5 in Rocket Launcher	18	4	-	-	17.7	1
423630	81 mm Mortar	12	3	12	-	17.8	20
435950	106 mm Recoilless Rifle (on Jeep)	1 per 6 sec	1	-	-	60.	4
435890	90 mm Recoilless Rifle[1]	1 per 6 sec	1	-	-	64.5	4
422585	7.62 mm Lt Machine Gun[2]	550	100	200	-	.089	75
420670	40 mm Grenade Launcher	-	-	-	-	.75	10
944695	5.56 mm Rifle (M-16)	-	-	-	-	-	-
429280	.45 cal Pistol	35-42	10	21-28	-	.057	20
435840	.38 cal Pistol	-	-	-	-	-	-
400300	SS-11B Heli Guided Missile	1/23 sec	-	-	6	156.	12
940065	UH-1D 7.62 mm (M-60) Side Door Gun XM-23 (1 each side)	500 ea	100 ea	200 ea	-	-	-
940067	LOH 7.62 mm (Dual M-60) XM-7 or M-2 (1 mg each side)	1100	200	400	1100	.089	2600
940077	UH-1B 2.75 in Rockets XM-3 (24 each side)	48/4 sec	48/4 sec	-	48	10.3	96
948927	UH-1B XM-16 (one set with 7 rkts/2 mg each side)						
	- 2.75 in Rockets (7 each side)	12/sec	-	-	14	-	-
	- 7.62 mm M-6 (M-60's each side)	2200	400	800	6700	.089	5200
-	UH-1B M-5 40 mm Grenade Launcher (one in nose)	220	-	-	150	-	-
-	*7.62 mm Rifle M14	700-750	-	-	-	.072	2
-	*30 cal Rifle, auto (Bng)	350-550	40-60	40-60 w/3 120-150 w/20	-	-	-
-	*30 cal Carbine	750-775	40-60	40-60	-	-	-
-	*45 cal Submachine Gun	-	-	-	-	.057	2
-	*30 cal Rifle (M-1)	-	8-10	16-24	-	-	-
-	*30 cal Machine Gun	600-675	75	150	-	-	-

[1]Basic load = Peak daily consumption (FM-101-10, pg 5-51) for 40 mm grenade launcher, 90 mm, 106 mm, and 2.75.

[2]7.62 mm substituted for cal 30 weapons (FM-101-10, pg 5-51).

[3]"Service Units - Basic Load": "service units not likely to become involved in direct combat with the enemy."

*Reference data; weapon not listed in Airmobile Division TOE.

		FM 101-10-1 (1966)						
...er Air ...ort (...nd/Day)	SB 38-26 (1963) (Rnd/Day)	Normal Engagement Meeting (Rnd/Day)	Maximum: Def of Pos 1st Day (Rnd/Day)	Minimum: Inactive Situation (Rnd/Day)	Basic Load (Rounds)	Carried By Weapon Carrier (Rounds)	Basic Load If Different From Inf Bn Area (Rounds)	Wt Per Rnd Without/With Container (Lb/Rnd)
45	64.	90	180	35	200	-	-	42/60
1	1.	2	6	1	6	3	6(Inf Bgde Hq)	9/17.7
20	31.6	40	80	16	120	80	-	13.25
4	4.3	-	-	-	40	6	-	44/60
4	1.3	2	5	1	18	6	-	9.25/15.
75	75.	-	-	-	3080	880	2200	.063/.089
10	7.	6	18	3	30	18	24(Inf Bgde Hq)	.50/.806
-	-	-	-	-	-	-	-	-
20	0.6	1	2	.2	31	21	21	.044/.057
-	-	-	-	-	-	-	-	-
12	-	-	-	-	36	6	-	61/150
-	-	-	-	-	7480	3740	-	.063/.089
2600	34.	-	-	-	6500	1300	-	.063/.089
96.	96.	-	-	-	192	48	-	18/27.2
-	-	-	-	-	-	-	-	-
5200	576.	-	-	-	21,600	7200	-	.063/.089
-	-	200	600	100	-	-	-	-
20	4.8 lt bbl 19.3 mod	-	-	-	340 lt bbl 740 mod	100 160	160 500	.055/.079
-	19.3	40	80	15	-	-	500	-
-	3.7	4	8	1	180	-	90	.044/.057
20	1.6	20	40	8	-	-	90	-
-	5.3	15	25	5	-	-	144	-
-	75.	100	200	40	-	-	2000	-

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TABLE LXX (C)

AMMUNITION RESUPPLY RATES PER WEAPON PER DAY (U)

Line Item No.	Weapon Description	Basic Load FM-101-10 (Rounds)		Battalion Area Rounds Per Day			
		BN	BGDE	Normal	Source	Maximum	Sou
418318	105 mm Howitzer	200	--	64	SB-38-26	180	FM 101
420670	40 mm Grenade Launcher	30	24	6	FM 101-10	30	FM 101
420800	3.5 in Rocker Launcher	-	6	-		-	
422585	7.62 mm Machine Gun	3,080	2,200	100	FM 101-10	200	FM 101
423630	81 mm Mortar	120	--	40	FM 101-10	80	FM 101
429280	.45 Cal Pistol	31	21	1	FM 101-10	2	FM 101
435840	.38 Cal Pistol	-	18	-		-	
435890	90 mm Rifle	18	--	4	CSSG Letter	10	5:2 Rati FM 101
435950	106 mm Rifle	40	--	4	CSSG Letter	10	Same a
944695	5.56 mm Rifle (XM16E1)	680	320	40	Assumed Based on Avail Data	80	Assume
40830	Helic Missile SS-11	-	36	-		-	
940065	UH-1D (Two 7.62 mm M-60 Side Door) XM-23	-	7,480	-		-	
940067	LOH (7.62 mm Dual M-60) XM-7 or M-2	-	6,500	-		-	
940077	UH-1B (2.75 Rockets) XM-3	-	192	-		-	
948927	UH-1B (2.75 Roc & M-60) SM-16						
	-- 2.75 Rockets (7 ea side)	-	56	-		-	
	-- 7.62 Mach Gun (2 ea side)	-	21,600	-		-	
	UH-1B (40 mm Grenade Lchr) M-5	-	600	-		-	

*Helicopter ordnance consumption is based on the following assumptions unless noted otherwise.

1. Normal day consists of 2 cycles average for all assigned helicopters.
2. Maximum day consists of 4 cycles average for all assigned helicopters.
3. Machine guns will expend 50% of the rounds on board each cycle for UH-1B and OH-6A; 25% for UH-1D
4. All 2.75 rockets and 40 mm M-5 grenades will be expended on each cycle.

ttalion Area Rounds Per Day			Brigade Base Rounds Per Day			
Source	Maximum	Source	Normal	Source	Maximum	Source
8-26	180	FM 101-10	--		--	
101-10	30	FM 101-10	5	Bn Times Ratio Basic Loads	24	FM 101-10 Footnote
	-		2	FM 101-10	6	FM 101-10
101-10	200	FM 101-10	72	Bn Times Ratio Basic Loads	144	Bn Times Ratio Basic Loads
101-10	80	FM 101-10	--		--	
101-10	2	FM 101-10	1	FM 101-10	2	FM 101-10
	-		1	FM 101-10 (Cal 45)	2	FM 101-10 (Cal 45)
G Letter	10	5:2 Ratio from FM 101-10	--		--	
G Letter	10	Same as 90 mm	--		--	
umed Based vail Data	80	Assumed	10	Assumed	20	Assumed
	-		12	CSSG Letter	24	*
	-		1,870	*	3,740	*
	-		1,300	*	2,600	*
	-		96	* Also CSSG Ltr & SB 38-26	192	* Also FM 101-10 Footnote
			28	*	56	* Also FM 101-10 Footnote
	-					
	-		7,200	*	14,400	*
	-		300	*	600	*

less noted otherwise.

s.
H-1B and OH-6A; 25% for UH-1D.
ycle.

TABLE LXXI (U)

BATTALION AREA DAILY FUEL CONSUMPTION

Line Item No	Description	In Bn HQ & HQ Co		Rifle Co (Each of 3)		105 Howitzer Battery		Engineering Platoon		Combat Support Co	
MOGAS (Gal/Day)		Nor	Max	Nor	Max	Nor	Max	Nor	Max	Nor	Max
---	Generator Sets	36.0	60.0	-	-	12.0	20.0	-	-	-	-
460080	3/4 T Truck	14.4	24.0	-	-	-	-	-	-	-	-
461206	1/2 T Truck Plat	32.0	53.6	8.0	13.4	4.0	6.7	-	-	20.0	33.5
461790	1/4 T Truck Jeep	17.2	28.4	-	-	8.6	14.2	4.3	7.1	4.3	7.1
947016	3/4 T Dump Truck	-	-	-	-	-	-	172.8	288.0	-	-
461793	1/4 T Truck (106 mm)	-	-	-	-	-	-	-	-	34.4	56.8
	TOTAL MOGAS (Gal/Day)	99.6	205.0	8.0	13.4	24.6	40.9	177.1	295.1	58.7	97.4
OIL AND LUBRICANTS (lb/Day)											
460080	3/4 T Truck	2.6	4.3	-	-	-	-	-	-	-	-
461206	1/2 T Truck Plat	9.0	15.0	2.2	3.8	1.1	1.9	-	-	5.6	9.4
461790	1/4 T Truck Jeep	4.7	7.7	-	-	2.3	3.8	1.2	1.9	1.2	1.9
947016	3/4 T Dump Truck	-	-	-	-	-	-	31.2	51.8	-	-
461793	1/4 T Truck (106 mm)	-	-	-	-	-	-	-	-	9.3	15.3
	TOTAL OIL AND LUBRICANTS (Lb/Day)	16.3	27.0	2.2	3.8	3.4	5.7	32.4	53.7	16.1	26.6

TABLE LXXII (C)

BATTALION AREA DAILY AMMUNITION CONSUMPTION
(ROUNDS/DAY) (U)

Weapons		Rounds Per Day									
Item No	Description	Inf Bn HQ & HQ Co		Rifle Co (Each of 3)		105 mm How Battery		Eng Platoon		Combat Supt Co	
		Nor	Max	Nor	Max	Nor	Max	Nor	Max	Nor	Max
420670	40 mm Gren Laun	48	240	144	720	18	90	18	90	36	180
423630	Motor 81 mm	-	-	120	240	-	-	-	-	160	320
429280	Pistol Cal 45	39	78	55	110	4	8	6	12	23	46
435950	Rifle 106 mm	-	-	-	-	-	-	-	-	32	80
418318	Howitzer 105 mm	-	-	-	-	384	1080	-	-	-	-
435890	Rifle 90 mm	-	-	24	60	-	-	-	-	-	-
944695	Rifle 5.56 mm	3800	7600	4600	9200	3400	6800	1400	2800	4000	8000
422585	Lt Mach Gun 7.62 mm	200	400	600	1200	600	1200	400	800	-	-

TABLE LXXIII (C)

BATTALION AREA DAILY AMMUNITION RESUPPLY QUANTITIES DELIVERED (U)

	105 mm Howitzer Battery				Bn Area Excl 105 mm How Btry			
	Normal		Maximum		Normal		Maximum	
Weapons	Rounds Shipped	Unpalletized Weight (lb)	Rounds Shipped	Unpalletized Weight (lb)	Rounds Shipped	Unpalletized Weight (lb)	Rounds Shipped	Unpalletized Weight (lb)
40 mm Gren Laun	72	53	144	106	648	476	2, 592	1, 904
Mortar 81 mm	-	-	-	-	480	9, 360	1, 040	20, 280
Pistol Cal . 45	NEGL (4)	-	NEGL (8)	-	NEGL (233)	-	NEGL (466)	-
Rifle 106 mm	-	-	-	-	30	1, 845	90	5, 535
Howitzer 105 mm	400	24, 000	1, 080	64, 800	-	-	-	-
Rifle 90 mm	-	-	-	-	72	3, 996	168	9, 324
Rifle 5. 56 mm	4, 320	120	7, 200	300	23, 040	960	46, 080	1, 920
Lt Mach Gun 7. 62 mm	1, 100	98	1, 100	98	2, 200	196	4, 400	392

TABLE LXXIV (U)

BRIGADE BASE DAILY FUEL CONSUMPTION

Line Item No	Description	Qty	MoGas Gal/Day Norm	MoGas Gal/Day Max	JP-4 Gal/Day Norm	JP-4 Gal/Day Max	Oil and Lubricants Pounds/Day Norm	Oil and Lubricants Pounds/Day Max
461790	1/4 T Truck	75	533	794	-	-	144.0	214.0
459832	1/4 T Amb	1	7	11	-	-	2.5	3.8
461206	1/2 T Truck	21	134	210	-	-	37.5	58
460050	3/4 T Truck	52	625	937	-	-	113.0	169.0
460080	3/4 T Truck	19	228	342	-	-	41.1	61.7
460110	2 1/2 T Truck	16	320	480	-	-	67.2	101.0
461329	2 1/2 T Fuel Truck	6	120	180	-	-	25.2	37.8
948910	Scooter	6	12	18	-	-	10.2	15.3
947016	3/4 T Dump Truck	1	12	18	-	-	2.2	3.2
405215	Lt Weapon Carrier	4	27	40	-	-	7.6	11.2
942825	3/4 T Trk w/Wrecker	1	12	18	-	-	2.2	3.2
732701	UH-1B	24	-	-	5,470	10,940	820.0	1640.0
732703	UH-1D	65	-	-	18,950	37,900	2840.0	5680.0
963245	LOH (OH-6A)	15	-	-	1,200	2,400	120.0	240.0
235152	Generator Sets	35	720	1260	-	-	-	-
	Total of Above		2730	4308	25,620	51,240	4232.7	8239.0
	Amount Delivered		3000	4500	25,500	51,500	4230	8240

TABLE LXXV (C)

BRIGADE BASE DAILY AMMUNITION CONSUMPTION (ROUNDS/DAY) (U)

Line Item No.	Weapons Description	Weapons Quantity	Rounds per Day Normal	Rounds per Day Maximum
420670	40 mm Gren Launcher (M-79)	48	240	1,152
42285	Lt Mach Gun 7.62	30	2,160	4,320
429280	Pistol Cal .45	93	93	186
435840	Pistol Cal .38	327	327	654
944695	Rifle 5.56 mm	748	7,480	14,960
40030	Helic Guid Miss SS-11B	4	48	96
420800	3.5 Inch Rocket Launcher	2	4	12
940065	Helic Arm XM-23	65	121,550	243,100
940067	Helic Arm XM-7	15	19,500	39,000
948927	Weap Sup Syst XM-16	12		
	2.75 Rocket (75% of Missions)	9 of 12	252	504
	40 mm Gren Launcher M-5 (25% of missions)	3 of 12	900	1,800
	7.62 mm Mach Gun (dual each side)	12	86,400	172,800
940071	Helic Arm 2.75 Rocket (XM-3)	12	1,152	2,304

TABLE LXXVI (C)

BRIGADE BASE DAILY AMMUNITION RESUPPLY QUANTITIES DELIVERED (U)

	Normal		Maximum	
Weapons Description	Rounds Shipped	Unpalletized Weight (lb)	Rounds Shipped	Jnpalletized Weight (lb)
40 mm Gren Launcher (M-79)	288	212	1,152	848
Lt Mach Gun 7.62 mm	2,200	196	4,400	382
Piston Cal .45	-	-	-	-
Pistol Cal .38	-	-	-	-
Rifle 5.56 mm	7,200	300	14,000	600
Helic Guid Miss SS-11B	48	7,200	96	14,400
3.5 Inch Rocket Launcher	3	56	12	224
7.62 mm M-60	230,400	19,200	460,800	38,400
2.75 Inch Rockets	1,360	32,300	2,800	66,500
Grenades, Mines and Pyrotechnics	-	5,980	-	8,970
40 mm Gren Launcher (M-5)	900	954	1,800	1,908

TABLE LXXVII (U)

TYPICAL CARGO CHARACTERISTICS

Description	Smallest Container Characteristics					Layer Characteristics			
	Length Inches	Width Inches	Width Inches	Content	Weight lb	Boxes Per Layer	Height Layer Inches	Weight Layer lb	Qu Per
Combat, Meal, Individual	18 1/2	12 3/8	4 7/8	12 meals	25	8	4 7/8	200	768 n
500 Gal Fabric Drums	80	47	47	500 gallons	3550	1	47	3550	1 dru
5 Gallon Jerry Cans	13 1/2	6 3/8	18 3/8	5 gallons	40 (MoGas)	21	18 3/8	840	21 ca
5.56 mm rifle	14 7/16	12 17/32	8 1/8	1440 rounds	60	12	8 1/8	720	34,5
7.62 mm rifle	15 1/4	13 1/4	11 1/8	1200	86	9	11 1/8	774	21,6
7.62 mm machine gun belted	15 1/8	13 1/4	11 1/8	1100 rounds	98	9	11 1/8	828	19,6
.45 caliber pistol	10 1/8	7 7/8	14 3/4	1200	68	25	14 3/4	1700	30,0
.38 caliber pistol	10 3/8	8 5/8	14 3/4	1200	50	25	14 3/4	1250	30,0
.50 cal machine gun belted	15 1/8	13 1/4	11 1/8	210 rounds	100	9	11 1/8	900	3,78
40 mm grenade (for M-79)	16 1/4	13 1/4	10 11/16	72	53	9	10 11/16	477	2,59
40 mm grenade linked (M-5)	23 3/4	13	6 13/16	50	53	6	6 13/16	318	1,80
3.5 inch rocket	29 5/8	14 1/8	6 5/8	3 rounds	56	24	29 5/8	1344	72 r
81 mm mortar (illum)	30 1/16	8 1/2	8 3/8	4 rounds	52	30	30 1/16	1560	80 r
90 mm rifle	39	13	7 3/8	2 rounds	111	4	7 3/8	444	24 r
106 mm rifle	47 5/8	13 1/8	8 1/8	2 rounds	123	3	8 1/8	469	30 r
Hand grenades offensive MK 3 A 2	17 5/8	13 3/16	8 15/32	20 grenades	45	15	17 5/8	675	600
105 mm howitzer	37 3/8	11 15/16	7 19/32	2 rounds	120	20	37 5/8	2400	40 r
Mine AT M-607 or 609	29 3/16	13 7/16	12 1/2	4 mines	90-95	12	29 3/16	1140	48 n
Mine AP M-16	17 3/4	9 5/8	7 31/32	4 mines	50.5	25	17 3/4	1262	100
Rifle Grenade (Smoke) M19A1	18 3/16	14 13/32	6 3/4	10 grenades	37	18	18 3/16	1660	180
7.62 mm for M-60	17 1/2	7 7/8	11 1/2	960 rounds	80	15	11 1/2	1200	14,
2.75 inch rockets	43 9/16	9	9 3/4	4 rockets	95	5	9 3/4	475	80 r
SS-11B	-	-	-	1 missile	150	4		600	12 r

*Includes 5-1/2-inch pallet height. **Includes 100 lb for pallet and steel banding.

ristics	Pallet Characteristics						
Weight Layer lb	Quantity Per Pallet Item	Layers	Length Inches	Width Inches	Height Inches*	Weight lb**	Reference
200	768 meals	8	48 (49 1/2)	40 (37)	44 1/2	1700	All pallet weights inch 100-lb pallet; all heights inch 5.5 in pallet
3550	1 drum	1	80	47	47	3600	
840	21 cans	1	48 (44 5/8)	40 (40 1/2)	23 7/8	940	
720	34,560 rounds	2	48 (50 1/8)	40 (43 5/16)	21 3/4	1540	WR-53/21
774	21,600 rounds	2	48 (45 3/8)	40 (39 3/4)	27 3/4	1648	
828	19,600 rounds	2	48 (45 3/8)	40 (39 3/4)	27 3/4	1840	
1700	30,000 rounds	1	48 (50 5/8)	40 (39 3/8)	19 3/4	1800	WR-55/24
1250	30,000 rounds	1	48 (51 7/8)	40 (43 1/8)	19 3/4	1350	WR-55/22
900	3,780 rounds	2	48 (45 3/8)	40 (39 3/4)	27 3/4	1707	
477	2,592	4	48 (48 3/4)	40 (39 3/4)	48 1/4	2008	ordnance drawing 8835104
318	1,800	6	48 (47 1/2)	40 (39)	47 1/2)	2008	ordnance drawing 8865431
1344	72 rockets	1	48 (53)	40 (42 3/8)	35 1/8	1450	WR-55/62
1560	80 rounds		48 (51)	40 (41 7/8)	35 9/16	1660	ordnance drawing 8864663, 8864657
444	24 rounds	3	48 (52)	40 (39)	27 5/8	1432	WR-55/34
469	30 rounds	5	48 (47 5/8)	40 (39 3/8)	46 1/8	1945	
675	600 grenades	2	48 (48 3/4)	40 (39 9/16)	40 3/4	1450	ordnance drawing 9211615, 9211614
2400	40 rounds	1	48	48 (47 1/2)	40 (39 15/32)	2500	ordnance drawing 7549072, 7549073
1140	48 mines	1	48 (50)	40 (40 5/16)	34 11/16	1240	ordnance drawing 8830860, 8830861
1262	100 mines	1	48 (48 3/8)	40 (39 3/4)	23 1/4	1362	ordnance drawing 8863365, 8863366
1660	180 grenades	1	48 (48 5/32)	40 (40.5)	23 11/16	1760	ordnance drawing 9207903, 9207902
1200	14,400 rounds	1	48 (52 1/2)	40 (39 3/8)	17	1300	WR-55/8
475	80 rockets	4	48 (45)	40 (43-9/16)	44 1/2	2000	WR-53/24
600	12 missile	3	-	-	-	1900	assumed

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TABLE LXXVIII (C)

BATTALION AREA DAILY RESUPPLY

(Including Container but Excluding Pallets and Rigging) (U)

Battalion Area Excluding 105 mm Howitzer Battery (802 Men)

Class	Commodity	Normal: Average Weight Per Pallet (lb)	Normal: Average Height Per Pallet (in.)	Normal: Total Weight (lb)	Number Pallets or 500 Gal Fuel Drums	Maximum: Average Weight Per Pallet (lb)	Maximum: Average Height Per Pallet (in.)	Maximum: Total Weight (lb)
I	Rations[1]	1,600	39	4,800	3	1,600	39	4,800
IA	Water[2]	-	-	(9,630)	-	-	-	(9,630)
II & IV	[3]	1,530	36	4,590	3	1,720	36	6,880
III	MoGas (500-gal drum)	3,400	47	3,400	1*	3,400	47	3,400
III	Oil & Lubricants	- } 1,693	- } 23	71.4	- } 1	- } 988	- } 12	115.7
V	7.62 mm Lt MG	-	-	196	-	-	-	392
	5.56 mm Rifle	-	-	960	2/3	1,440	17	1,920
	40 mm Grenades	-	11	476	1/4	1,904	43	1,904
	Grenades, Mines, & Pyrotechnics[4]	2,005	45	4,010	2	2,005	45	6,015
	81 mm Mortar	1,560	31	9,360	6	1,560	31	20,280
	90 mm Rifle	1,332	23	3,996	3	1,332	23	9,324
	106 mm Rifle	1,845	41	1,845	1	1,845	41	5,535
	105 mm Howitzer	-	-	-	-	-	-	-
	Total (Weight and 40x48 in Equivalent Pallets)			33,704	21			60,568

1. 6 pounds per man per day.
2. 1.5 gallons (12 pounds) per man per day in the Battalion Area; not transported by XC-142A.
3. 5.75 pounds per man per day (pg 65 of ref 50); increased 50 percent for maximum.
4. 7.5 pounds per man per day maximum and 5 pounds per man per day normal (pg 70 of ref 50).

* 500-gallon fuel drum.

owitzer Battery (802 Men)					105 mm Howitzer Battery (89 Men)							
Maximum							Normal			Maximum		
verage Weight Per Pallet (lb)	Average Height Per Pallet (in.)	Total Weight (lb)	Number Pallets or 500 Gal Fuel Drums		Average Weight Per Pallet (lb)	Average Height Per Pallet (in.)	Total Weight (lb)	Number Pallets or 500 Gal Fuel Drums		Total Weight (lb)	Number Pallets or 500 Gal Fuel Drums	
,600	39	4,800	3				550	3/8		550	3/8	
-	-	(9,630)	-				(1,068)	-		(1,068)	-	
,720	36	6,880	4				512	-		768	-	
,400	47	3,400	1*				200 (5x5-gal)	-		320 (8x5-gal)	-	
- 988	- 12	115.7	-		991 Nor	18 Nor	3.4	-	2	5.7	-	3
-	-	392	-	1	938 Max	18 Max	98	-		98	-	
,440	17	1,920	1/3				120	-		300	1/5	
,904	43	1,904	1				53	-		106	-	
,005	45	6,015	3				445	1/4		668	1/3	
,560	31	20,280	13		-	-	-	-		-	-	
,332	23	9,324	7		-	-	-	-		-	-	
,845	41	5,535	3		-	-	-	-		-	-	
-	-	-	-		2,400	38	24,000	10		64,800	27	
		60,568	38				25,982	12		67,606	30	

ed by XC-142A.
ximum.
(pg 70 of ref 50).

TABLE LXXIX (C)

BRIGADE BASE DAILY RESUPPLY

(Including Containers But Excluding Pallets and Rigging) (U)

Class	Commodity	Average Weight Per Pallet (lb)	Average Height Per Pallet (in)	Total Weigh (lb)
I	Rations [1]	1,600	39	8,00
IA	Water [2]	-	-	(28,70
II & IV	- [3]	1,720	40	6,88
III	MoGas (500-Gal Drum)	3,400	47	20,40
IIIA	JP-4 (500-Gal Drum)	3,600	47	183,70
III & IIIA	Oil & Lubricants	2,120	42	4,23
V	40 mm grenade (M-79)	1,684 (Nor)	36 (Nor)	21
	7.62 mm lt. MG.	2,094 (Max)	39 (Max)	19
	5.56 mm rifle	(Combined		30
	3.5 in rkt. lchr.	Weights)		5
	.38/.45 cal. pistol			2
VA	Grenades, mines, and Pyrotechnics [4]	1,495	40	5,98
	Helic Guid Miss SS-11B	1,800	36	7,20
	7.62 mm M-60	1,200	12	19,20
	2.75 in Rocket	1,900	39	32,30
	40 mm Grenade (M-5)	1,908	42	95
Total (weight and number of 40 x 48-inch pallet equilavent)		-	-	289,6

1. 6 pounds per man per day.
2. 3 gallons (24 pounds) per man per day at Brigade Base; not transported by XC-142A
3. [illegible].75 pounds per man per day (pg. 65 of ref 50); increased 50 percent for maximum combat inte
4. 7.5 pounds per man per day maximum and 5 pounds per man per day normal (pg. 70 of ref 50).
* 500-gallon fuel drums.

(U)

Average Height Per Pallet (in)	Total Weight (lb)	Number Pallets Or 500-Gal Fuel Drum	Total Weight (lb)	Number Pallets Or 500-Gal Fuel Drum
39	8,000	5	8,000	5
-	(28,704)	-	(28,704)	-
40	6,880	4	10,320	6
47	20,400	6*	30,600	9*
47	183,700	51*	370,800	103*
42	4,230	2	8,240	4
36 (Nor)	212		848	
39 (Max)	196		382	
	300	1	600	1
	56		224	
	20		40	
40	5,980	4	8,970	6
36	7,200	4	14,400	8
12	19,200	16	38,400	32
39	32,300	17	66,500	35
42	954	1/2 Pallet	1,908	1
		incl above		
-	289,628	167	560,232	322

ansported by XC-142A
0 percent for maximum combat intensity.
er day normal (pg. 70 of ref 50).

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(C) APPENDIX II

TABULAR RESULTS (U)

TABLE LXXX (C)

DISTRIBUTION OF CARGO WEIGHTS AND HEIGHTS; NORMAL COMBAT INTENSITY (U)

		Number Modules in Weight Range and Heights of Cargo									
		Battalion Area Excl 105 mm How Btry		105 mm Howitzer Battery		Total Battalion Area (1 of 3)		Brigade Base		Total Brigade Area	
Cargo Base Size (in)	Weight Range (lb)	Height (in)	Number	Height (in)	Number	Height (in)	Number	Height (in)	Number	Height (in)	Number
40 x 48	901 - 1000 Inclusive			18	2	18	2			6 x 18	6
	- 1100	-	-	-	-	-	-	-	-	-	-
	- 1200	-	-	-	-	-	-	17	16	17	16
	- 1300	-	-	-	-	-	-	-	-	-	-
	- 1400	23	3	-	-	23	3			23	9
	- 1500							40	4	40	4
	- 1600	3 x 39 3 x 36 6 x 31	12	-	-	6 x 31 3 x 36 3 x 39	12	39	5	18 x 31 9 x 36 9 x 39	41
	- 1700	23	1	-	-	23	1	36	1	1 x 36 3 x 23	4
	- 1800	-	-	-	-	-	-	4 x 40 4 x 36	8	4 x 36 4 x 40	8
	- 1900	41	1	-	-	41	1	39	17	17 x 39 3 x 41	20
	- 20[illegible]	-	-	-	-	-	-	-	-	-	-
	- [illegible]00	45	2			45	2			45	6
	- 2200	-	-	-	-	-	-	42	2	42	2
	- 2300	-	-	-	-	-	-	-	-	-	-
	- 2400	-	-	38	10	38	10	-	-	38	30
	- 2500	-	-	-	-	-	-	-	-	-	-
80 x 47	- 3400	47	1*	-	-	47	1*	47	6*	47	9*
	- 3600	-	-	-	-	-	-	47	51*	47	51*
Total 40 x 48 equivalents			21		12		33		167		266

* 500-gallon fuel drum.

TABLE LXXXII (C)

DAILY RESUPPLY; 87°F/SL; STOL-LAND; BRIGADE BASE (144.8/280.1 TONS/DAY) (C)

Delivery System & Combat Intensity	Radius (N.Mi.)	Cycles	Total Flight Hours	Number Aircraft (Daily Util)	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Cost Cargo Lost	Total Fuel Cost	Total Spares Cost	Total Rigging & Packing Cost	Total Variable Operating Cost
Conventional (Normal)	50	19.7	11.0	2.75	-	-	4,750	-	542	650	1,664	7,606
	100	20.5	19.18	4.80	-	-	4,940	-	841	1,148	1,664	8,593
	125	20.9	23.5	5.88	-	-	5,040	-	1,010	1,410	1,664	9,124
	150	21.3	27.7	6.93	-	-	5,130	-	1,172	1,661	1,664	9,627
	185*	22.0	34.6	8.65	-	-	5,300	-	1,427	2,080	1,664	10,461
	200	22.4	37.6	9.40	-	-	5,400	-	1,546	2,240	1,664	10,850
	350	29.5	83.1	0.78	-	-	7,110	-	3,240	4,960	1,664	16,974
Vertical/ Modular (Normal)	50	20.9	11.7	2.93	-	-	5,240	-	575	724	1,664	8,203
	100	21.7	20.3	5.08	-	-	5,440	-	890	1,276	1,664	9,270
	125	22.2	25.0	6.25	-	-	5,580	-	1,070	1,576	1,664	9,890
	150	22.6	29.4	7.35	-	-	5,670	-	1,243	1,851	1,664	10,428
	185*	23.4	36.8	9.2	-	-	5,880	-	1,517	2,320	1,664	11,381
	200	23.9	40.2	10.05	-	-	6,000	-	1,649	2,510	1,664	11,823
	350	31.6	89.0	22.25	-	-	7,930	-	3,480	5,570	1,664	18,644
Conventional (Maximum)	50	38.1	21.3	-	32.8	2.73	11,470	-	1,048	1,257	3,220	16,995
	100	39.6	37.0	-	48.9	4.08	11,900	-	1,624	2,220	3,220	18,964
	125	40.4	45.5	-	57.6	4.80	12,180	-	1,953	2,730	3,220	20,083
	150	41.3	53.6	-	66.0	5.50	12,420	-	2,270	3,220	3,220	21,130
	185*	42.4	66.6	-	79.3	6.60	12,770	-	2,750	4,000	3,220	22,740
	200	43.3	72.6	-	85.6	7.13	13,030	-	2,990	4,330	3,220	23,570
	350	57.0	160.5	-	177.6	14.78	17,160	-	6,270	9,580	3,220	36,230
Vertical/ Modular (Maximum)	50	40.4	22.6	-	34.7	2.89	12,700	-	1,111	1,400	3,220	18,431
	100	42.1	39.3	-	51.9	4.33	13,210	-	1,726	2,480	3,220	20,636
	125	42.9	48.3	-	61.2	5.10	13,480	-	2,070	3,040	3,220	21,810
	150	43.9	57.0	-	70.2	5.85	13,790	-	2,420	3,600	3,220	23,030
	185*	45.2	70.9	-	84.5	7.04	14,190	-	2,930	4,470	3,220	24,810
	200	46.3	77.7	-	91.6	7.62	14,540	-	3,200	4,860	3,220	25,820
	350	61.2	172.2	-	190.6	15.87	19,220	-	6,730	10,800	3,220	39,970

* Break in Payload/Radius Curve.

TABLE LXXXIII (C)

DAILY RESUPP[illegible] 2000 FT; STOL-LAND; BRIGADE BASE (144.8/280.1 TONS/DAY) (C)

Delivery System Combat Intensity	Radius (N. Mi.)	Cycles	Total Flight Hours	Number Aircraft (Daily Util)	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Cost Cargo Lost	Total Fuel Cost	Total Spares Cost	Total Rigging & Packing Cost	Total Variable Oper. Cost
Conven-tional (Normal)	50	19.6	10.95	2.74	-	-	4,720	-	529	650	1,664	7,563
	100	20.4	19.1	4.78	-	-	4,910	-	816	1,142	1,664	8,532
	125	20.8	23.4	5.85	-	-	5,010	-	972	1,403	1,664	9,049
	150	21.2	27.6	6.89	-	-	5,110	-	1,145	1,654	1,664	9,573
	193*	21.9	35.7	8.93	-	-	5,280	-	1,428	2,150	1,664	10,522
	200	22.1	37.1	9.28	-	-	5,330	-	1,481	2,210	1,664	10,685
	350	28.3	79.7	19.93	-	-	6,820	-	3,030	4,750	1,664	16,264
Vertical/ Modular (Normal)	50	20.8	11.65	2.91	-	-	5,220	-	562	721	1,664	8,167
	100	21.6	20.2	5.05	-	-	5,420	-	864	1,270	1,664	9,218
	125	22.1	24.8	6.20	-	-	5,540	-	1,032	1,562	1,664	9,798
	150	22.5	29.2	7.30	-	-	5,650	-	1,215	1,843	1,664	10,372
	193*	23.3	38.0	9.50	-	-	5,840	-	1,520	2,390	1,664	11,054
	200	23.5	39.5	9.88	-	-	5,900	-	1,575	2,470	1,664	11,609
	350	30.8	86.8	21.7	-	-	7,730	-	3,300	5,430	1,664	18,124
Conven-tional (Maximum)	50	38.0	21.3	-	32.7	2.72	11,440	-	1,026	1,254	3,220	16,940
	100	39.4	36.8	-	48.6	4.05	11,870	-	1,576	2,210	3,220	18,876
	125	40.1	45.1	-	57.1	4.76	12,080	-	1,873	2,710	3,220	19,883
	150	40.9	53.2	-	65.5	5.46	12,320	-	2,210	3,190	3,220	20,940
	193*	42.4	69.1	-	81.8	6.81	12,780	-	2,770	4,140	3,220	22,910
	200	42.7	71.7	-	84.5	7.03	12,860	-	2,860	4,270	3,220	23,210
	350	54.7	154.0	-	170.4	14.20	16,470	-	5,850	9,190	3,220	34,730
Vertical/ Modular (Maximum)	50	40.2	22.5	-	34.6	2.88	12,620	-	1,085	1,393	3,220	18,318
	100	41.8	39.1	-	51.6	4.30	13,120	-	1,672	2,460	3,220	20,472
	125	42.6	47.9	-	60.7	5.06	13,370	-	1,990	3,020	3,220	21,600
	150	43.4	56.4	-	69.4	5.78	13,630	-	2,340	3,550	3,220	22,740
	193*	45.1	73.4	-	86.9	7.24	14,140	-	2,940	4,630	3,220	24,930
	200	45.4	76.4	-	90.0	7.50	14,270	-	3,040	4,770	3,220	25,300
	350	59.6	168.0	-	185.9	15.48	18,700	-	6,380	10,510	10,510	38,810

* Break in Payload/Radius Curve.

TABLE LXXXIV (C)

DAILY RESUPPLY; 87°F/SL; VTOL-LAND; BRIGADE BASE (144.8/280.1 TONS/DAY) (C)

Delivery System & Combat Intensity	Radius (N. Mi.)	Cycles	Total Flight Hours	Number Aircraft (Daily Util)	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Cost Cargo Lost	Total Fuel Cost	Total Spares Cost	Total Rigging & Packing Cost	Total Variable Operating Cost
Conventional (Normal)	50	31.8	20.3	5.08	-	-	7,670	-	1,049	1,208	1,664	11,591
	100	33.8	34.5	8.63	-	-	8,150	-	1,589	2,062	1,664	13,465
	125	34.9	42.2	10.55	-	-	8,760	-	1,896	2,540	1,664	14,500
	150	36.1	50.4	12.60	-	-	8,700	-	2,202	2,996	1,664	15,562
	200	38.9	68.5	17.13	-	-	9,380	-	2,918	4,085	1,664	18,047
	350	50.1	145.3	36.43	-	-	12,080	-	5,862	8,667	1,664	28,273
Vertical/ Modular (Normal)	50	28.8	18.43	4.61	-	-	7,230	-	950	1,149	1,664	10,993
	100	30.6	31.2	7.80	-	-	7,680	-	1,438	1,958	1,664	12,740
	125	31.6	38.3	9.58	-	-	7,940	-	1,716	2,410	1,664	13,730
	150	32.6	45.5	11.38	-	-	8,180	-	1,989	2,839	1,664	14,672
	200	34.8	61.2	15.30	-	-	8,730	-	2,610	3,828	1,664	16,832
	350	43.6	126.4	31.60	-	-	10,920	-	5,101	7,920	1,664	25,605
Conventional (Maximum)	50	61.4	39.3	-	51.6	4.30	18,480	-	2,026	2,333	3,220	26,059
	100	65.4	66.7	-	79.8	6.65	19,700	-	3,074	2,989	3,220	29,983
	125	67.6	81.8	-	95.3	7.93	20,400	-	3,670	4,910	3,220	32,200
	150	69.9	97.6	-	111.6	9.71	21,000	-	4,264	5,802	3,220	34,286
	200	75.2	132.3	-	147.4	12.28	22,600	-	5,640	7,896	3,220	39,356
	350	96.9	281.0	-	300.4	25.0	29,200	-	11,337	16,764	3,220	60,521
Vertical/ Modular (Maximum)	50	55.8	35.7	-	46.9	3.91	17,500	-	1,841	2,226	3,220	24,787
	100	59.2	60.4	-	72.3	6.03	18,600	-	2,782	3,789	3,220	28,391
	125	61.1	73.9	-	86.1	7.17	19,200	-	3,320	4,660	3,220	30,400
	150	63.1	88.1	-	100.7	8.38	19,800	-	3,849	5,496	3,220	32,365
	200	67.4	118.7	-	132.2	11.02	21,200	-	5,055	7,414	3,220	36,889
	350	84.3	245.0	-	261.9	21.8	26,500	-	9,863	15,313	3,220	54,896

TABLE LXXXV (C)

DAILY RESUPPLY: 83°F/2000 FT; VTOL-LAND; BRIGADE BASE (144.8/280.1 TONS/DAY) (C)

Delivery System & Combat Intensity	Radius (N. Mi.)	Cycles	Total Flight Hours	Number Aircraft (Daily Util)	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Cost Cargo Lost	Total Fuel Cost	Total Spares Cost	Total Rigging & Packing Cost	Total Variable Operating Cost
Conventional (Normal)	50	37.6	23.4	5.85	-	-	9,060	-	1,278	1,429	1,664	13,421
	100	40.2	41.0	10.25	-	-	9,690	-	1,889	2,452	1,664	15,695
	125	41.8	50.3	12.58	-	-	10,080	-	2,250	3,040	1,664	17,034
	150	43.3	60.4	15.10	-	-	10,420	-	2,598	3,594	1,664	18,276
	200	46.9	82.5	20.63	-	-	11,300	-	3,471	4,924	1,664	21,359
	350	62.5	181.2	45.30	-	-	15,070	-	7,000	10,813	1,664	34,547
Vertical/ Modular (Normal)	50	34.0	21.8	5.45	-	-	8,540	-	1,156	1,357	1,664	12,717
	100	36.2	36.9	9.23	-	-	9,080	-	1,701	2,317	1,664	14,762
	125	37.5	45.2	11.30	-	-	9,400	-	2,020	2,860	1,664	15,944
	150	38.7	54.1	13.53	-	-	9,720	-	2,322	3,371	1,664	17,077
	200	41.6	73.2	18.30	-	-	10,420	-	3,078	4,576	1,664	19,738
	350	52.9	153.6	38.40	-	-	13,270	-	5,925	9,609	1,664	30,468
Conventional (Maximum)	50	72.6	46.4	-	60.9	5.08	21,800	-	2,468	2,759	3,220	30,247
	100	77.8	79.4	-	95.0	7.92	23,400	-	3,657	4,746	3,220	35,023
	125	80.7	97.7	-	113.9	9.50	24,300	-	4,340	5,860	3,220	37,720
	150	83.8	117.0	-	133.8	11.15	25,200	-	5,028	6,955	3,220	40,403
	200	90.8	159.7	-	177.9	14.83	27,300	-	6,719	9,534	3,220	46,773
	350	120.8	350.0	-	374.2	31.2	36,400	-	13,530	20,898	3,220	74,048
Vertical/ Modular (Maximum)	50	65.8	42.1	-	55.3	4.61	20,700	-	2,237	2,625	3,220	28,782
	100	69.9	71.3	-	85.3	7.11	22,000	-	3,285	4,474	3,220	32,979
	125	72.4	87.6	-	102.1	8.50	22,700	-	3,900	5,520	3,220	35,340
	150	74.7	104.2	-	119.2	9.93	23,500	-	4,482	6,506	3,220	37,708
	200	80.3	141.2	-	157.3	13.12	25,200	-	5,942	8,833	3,220	43,195
	350	102.3	297.0	-	317.5	2.65	30,800	-	11,458	18,583	3,220	64,061

TABLE LXXXVI (C)

DAILY RESUPPLY; 87°F/SL; VTOL/LAND; BATTALION AREA (29.74/63.79 TONS/DAY) (C)

Delivery System & Combat Intensity	Radius (N. Mi.)	Cycles	Total Flight Hours	Number Aircraft (Daily Util)	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Cost Cargo Lost	Total Fuel Cost	Total Spares Cost	Total Rigging & Packing Cost	Total Variable Operating Cost
Conventional (Normal)	50	6.79	4.35	1.09	-	-	3,200	-	227	261	342	4,030
	100	7.24	7.39	1.85	-	-	3,410	-	341	443	342	4,536
	150	7.74	10.83	2.71	-	-	3,640	-	474	651	342	5,107
	200	8.32	14.64	3.66	-	-	3,920	-	624	878	342	5,764
	350	10.69	31.0	7.75	-	-	5,030	-	1,248	1,860	342	8,480
Vertical/ Modular (Normal)	50	6.18	3.96	0.99	-	-	3,030	-	206	249	342	3,827
	100	6.54	6.68	1.67	-	-	3,080	-	308	421	342	4,281
	150	6.97	9.76	2.44	-	-	3,420	-	427	615	342	4,804
	200	7.44	13.10	3.28	-	-	3,650	-	558	826	342	5,376
	350	9.29	27.0	6.75	-	-	4,560	-	1,083	1,700	342	7,685
Conventional (Maximum)	50	14.57	9.31	-	12.23	1.02	11,080	-	486	559	733	12,858
	100	15.50	15.82	-	18.92	1.58	11,780	-	729	948	733	14,190
	150	16.60	23.2	-	26.5	2.21	12,620	-	1,017	1,395	733	15,765
	200	17.82	31.4	-	35.0	2.92	13,530	-	1,337	1,882	733	17,482
	350	22.94	66.6	-	71.2	5.94	17,470	-	2,680	4,000	733	24,883
Vertical/ Modular (Maximum)	50	13.23	8.49	-	11.14	0.93	10,490	-	443	535	733	12,201
	100	14.03	14.31	-	17.12	1.43	11,120	-	659	902	733	13,414
	150	14.94	20.9	-	23.9	1.99	11,860	-	914	1,318	733	14,825
	200	15.92	28.0	-	31.2	2.60	12,620	-	1,194	1,767	733	16,314
	350	19.91	57.7	-	61.7	5.14	15,780	-	2,320	3,640	733	22,473

TABLE LXXXVII (C)

DAILY RESUPPLY; 83^{O}F/2000 FT; VTOL/LAND; BATTALION AREA (29.74/63.79 TONS/DAY) (C)

Delivery System & Combat Intensity	Radius (N. Mi.)	Cycles	Total Flight Hours	Number Aircraft (Daily Util)	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Cost Cargo Lost	Total Fuel Cost	Total Spares Cost	Total Rigging & Packing Cost	Total Variable Operating Cost
Conven-	50	8.06	5.16	1.29	-	-	3,790	-	274	309	342	4,715
tional	100	8.62	8.79	2.20	-	-	4,060	-	403	527	342	5,332
(Normal)	150	9.28	13.00	3.25	-	-	4,370	-	560	780	342	6,052
	200	9.97	17.56	4.39	-	-	4,690	-	733	1,052	342	6,817
	350	13.4	38.8	9.70	-	-	6,310	-	1,502	2,330	342	10,484
Vertical/	50	7.28	4.66	1.17	-	-	3,580	-	248	294	342	4,464
Modular	100	7.73	7.89	1.97	-	-	3,800	-	362	497	342	5,001
(Normal)	150	8.26	11.56	2.89	-	-	4,050	-	498	727	342	5,617
	200	8.85	15.58	3.90	-	-	4,340	-	651	982	342	6,315
	350	11.2	32.5	8.13	-	-	5,500	-	1,255	2,050	342	9,147
Conven-	50	17.27	11.22	-	14.67	1.22	13,110	-	586	662	733	15,091
tional	100	18.47	18.83	-	22.53	1.88	14,030	-	864	1,130	733	16,757
(Maximum)	150	19.88	27.8	-	31.8	2.65	15,110	-	1,198	1,670	733	18,711
	200	21.5	37.8	-	42.1	3.51	16,340	-	1,580	2,270	733	20,923
	350	28.7	83.2	-	88.9	7.41	21,800	-	3,220	4,990	733	30,743
Vertical/	50	15.59	9.98	-	13.10	1.09	12,370	-	530	629	733	14,262
Modular	100	16.52	16.84	-	20.21	1.68	13.090	-	773	1,061	733	15,657
(Maximum)	150	17.68	24.8	-	28.3	2.36	14,030	-	1,067	1,562	733	17,392
	200	18.81	33.1	-	36.9	3.08	14,920	-	1,382	2,090	733	19,125
	350	24.2	70.2	-	75.0	6.25	19,200	-	2,710	4,420	733	27,063

TABLE LXXXVIII (C)

DAILY RESUPPLY; 87°F/SL; HOVER-DROP; BATTALION AREA (29.74/63.79 TONS/DAY) (C)

Delivery System & Combat Intensity	Radius (N. Mi.)	Cycles	Total Flight Hours	Number Aircraft (Daily Util)	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Cost Cargo Lost	Total Fuel Cost	Total Spares Cost	Total Rigging & Packing Cost	Total Variable Operating Cost
Conven-	50	10.20	5.71	1.43	-	-	3,320	858	279	342	3,010	7,809
tional	100	10.20	9.53	2.38	-	-	3,320	858	420	572	3,010	8,180
(Normal)	150	10.20	13.27	3.32	-	-	3,320	858	563	796	3,010	8,547
	200	10.20	17.13	4.28	-	-	3,320	858	702	1,028	3,010	8,918
	330*	10.20	27.0	6.75	-	-	3,320	858	1,072	1,622	3,010	9,882
	350	10.57	29.7	7.43	-	-	3,440	858	1,127	1,782	3,010	10,217
Vertical/	50	6.04	3.38	0.85	-	-	2,060	-	165	213	1,460	3,898
Modular	100	6.38	5.96	1.49	-	-	2,170	-	263	375	1,460	4,268
(Normal)	150	6.74	8.77	2.19	-	-	2,290	-	372	552	1,460	4,674
	200	7.16	12.02	3.01	-	-	2,440	-	492	757	1,460	5,149
	350	8.81	24.8	6.20	-	-	3,000	-	972	1,558	1,460	6,990
Conven-	50	21.9	12.27	-	16.65	1.39	10,300	1,840	596	734	6,440	19,912
tional	100	21.9	20.5	-	24.9	2.08	10,300	1,840	903	1,228	6,440	20,711
(Maximum)	150	21.9	28.5	-	32.9	2.74	10,300	1,840	1,208	1,708	6,440	21,496
	200	21.9	36.8	-	41.2	3.44	10,300	1,840	1,508	2,200	6,440	22,280
	330*	21.9	58.1	-	62.5	5.21	10,300	1,840	2,300	3,480	6,440	24,360
	350	22.7	63.8	-	68.3	5.69	10,690	1,840	2,510	5,020	6,440	26,500
Vertical/	50	12.93	7.24	-	8.96	0.75	6,350	-	353	456	3,130	10,289
Modular	100	13.67	12.77	-	14.59	1.22	6,700	-	562	804	3,130	11,196
(Maximum)	150	14.43	18.78	-	20.7	1.72	7,080	-	797	1,182	3,130	12,189
	200	15.32	25.7	-	27.7	2.31	7,520	-	1,053	1,620	3,130	13,323
	350	18.87	53.0	-	55.5	4.62	9,260	-	2,080	3,340	3,130	17,810

* Break in Payload/Radius Curve.

TABLE LXXXIX (C)

DAILY RESUPPLY; 83^{o}F/2000 FT; HOVER-DROP; BATTALION AREA (29.74/63.79 TONS/DAY) (C)

Delivery System & Combat Intensity	Radius (N. Mi.)	Cycles	Total Flight Hours	Number Aircraft (Daily Util)	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Cost Cargo Lost	Total Fuel Cost	Total Spares Cost	Total Rigging & Packing Cost	Total Variable Operating Cost
Conventional (Normal)	50	10.20	5.71	1.43	-	-	3,320	858	272	343	3,010	7,803
	100	10.20	9 53	2.38	-	-	3,320	858	408	572	3,010	8,168
	210*	12.20	17.96	4.49	-	-	3,320	858	714	1,078	3,010	8,980
	250	10.88	22.4	5.60	-	-	3,550	858	879	1,344	3,010	9,641
	300	11.85	28.8	7.20	-	-	3,860	858	1,115	1,727	3,010	10,570
	350	13.03	36.6	9.15	-	-	4,250	858	1,398	2,200	3,010	11 716
Vertical/ Modular (Normal)	50	7.03	3.94	0.99	-	-	2,390	-	188	248	1,460	4,286
	100	7.44	6.95	1.74	-	-	2,530	-	298	438	1,460	4,726
	150	7.90	10.28	2.57	-	-	2,690	-	428	648	1,460	5,226
	200	8.46	14.20	3.55	-	-	2,880	-	569	894	1,460	5,803
	350	10.62	29.9	7.48	-	-	3,610	-	1,140	1,879	1,460	8,089
	50	21.9	12.27	-	16.65	1.39	10,300	1,840	584	736	6,440	19,900
	100	21.9	20.5	-	24.9	2.08	10,300	1,840	877	1,229	6,440	20,686
	210*	21.9	38.5	-	42.9	3.58	10,300	1,840	1,533	2,310	6,440	22,423
	250	23.4	48.2	-	52.9	4.41	11,020	1,840	1,892	2,900	6,440	24,092
	300	25.5	61.8	-	66.9	5.58	12,000	1,840	2,400	3,710	6,440	26,390
	250	28.0	78.6	-	84.2	7.02	13,190	1,840	3,000	4,720	6,440	29,190
Vertical/ Modular (Maximum)	50	15.04	8.42	-	10.42	0.87	7,380	-	401	530	3,130	11,441
	100	15.92	14.88	-	17.00	1.42	7,810	-	636	937	3,130	12,513
	150	16.92	22.0	-	24.3	2.02	8,300	-	883	1,384	3,130	13,697
	200	18.12	30.4	-	32.8	2.73	8,890	-	1,208	1,918	3,130	15,146
	350	22.76	63.9	-	66.9	5.58	11,170	-	2,440	4,040	3,130	20,780

*Break in Payload/Radius Curve.

TABLE XC (C)

DAILY RESUPPLY; 87^{o}F/SL; AIRDROP (700-YARD DROP ZONE); BATTALION AREA (29.74/63.79 TONS/DAY) (C)

Delivery System & Combat Intensity	Radius (N. Mi.)	Cycles	Total Flight Hours	Number Aircraft (Daily Util)	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Cost Cargo Lost	Total Fuel Cost	Total Spares Cost	Total Rigging & Packing Cost	Total Variable Operating Cost
Conven-tional (Normal)	50	5.14	2.88	0.72	-	-	1,240	3,310	116	173	23,800	28,639
	100	5.14	4.81	1.23	-	-	1,240	3,310	187	288	23,800	28,825
	146*	5.14	6.59	1.65	-	-	1,240	3,310	252	395	23,800	28,997
	200	5.57	9.36	2.34	-	-	1,343	3,310	358	561	23,800	29,372
	350	7.22	20.3	5.08	-	-	1,740	3,310	765	1,218	23,800	30,833
Vertical/ Modular (Normal)	50	4.67	2.62	0.66	-	-	1,172	3,190	106	165	21,500	26,133
	100	5.00	4.67	1.17	-	-	1,250	3,190	182	294	21,500	26,416
	150	5.35	6.96	1.74	-	-	1,342	3,190	270	439	21,500	26,741
	200	5.77	9.69	2.42	-	-	1,448	3,190	370	611	21,500	27,119
	350	7.61	21.4	5.35	-	-	1,909	3,190	806	1,346	21,500	28,751
Conven-tional (Maximum)	50	11.02	6.17	-	9.48	0.79	3,320	7,090	249	371	51,100	62,130
	100	11.02	10.30	-	13.61	1.13	3,320	7,090	400	617	51,100	62,527
	146*	11.02	14.12	-	17.43	1.45	3,320	7,090	539	846	51,100	62,895
	200	11.92	20.0	-	23.6	1.97	3,590	7,090	765	1,202	51,100	63,747
	350	15.47	43.4	-	48.0	4.00	4,650	7,090	1,638	2,610	51,100	67,088
Vertical/ Modular (Maximum)	50	9.99	5.60	-	6.93	0.58	3,140	6,830	226	353	46,000	56,549
	100	10.70	10.00	-	11.42	0.95	3,360	6,830	388	630	46,000	57,208
	150	11.47	14.90	-	16.43	1.37	3,600	6,830	579	939	46,000	57,948
	200	12.38	20.8	-	22.4	1.87	4,220	6,830	795	1,311	46,000	59,156
	350	16.30	45.8	-	48.0	4.00	5,120	6,830	1,729	2,880	46,000	62,559

*Break in Payload/Radius Curve.

TABLE XCI (C)

DAILY RESUPPLY; 83°F/2000 FT; AIRDROP (450-YARD DROP ZONE); BATTALION AREA (29.74/63.79 TONS/DAY) (C)

Delivery System & Combat Intensity	Radius (N. Mi.)	Cycles	Total Flight Hours	Number Aircraft (Daily Util)	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Cost Cargo Lost	Total Fuel Cost	Total Spares Cost	Total Rigging & Packing Cost	Total Variable Operating Cost
Conven-	50	5.80	3.25	0.81	-	-	1,398	11,820	126	195	23,800	37,339
tional	100	5.80	5.42	1.36	-	-	1,398	11,820	208	325	23,800	37,551
(Normal)	146*	5.80	7.42	1.86	-	-	1,398	11,820	282	445	23,800	37,745
	200	6.24	10.48	2.62	-	-	1,503	11,380	398	629	23,800	37,710
	350	7.98	22.4	5.60	-	-	1,922	10,270	846	1,412	23,800	38,250
Vertical/	50	5.26	2.94	0.74	-	-	1,318	11,280	115	185	21,500	34,398
Modular	100	5.59	5.23	1.31	-	-	1,403	10,860	200	329	21,500	34,292
(Normal)	150	5.96	7.74	1.94	-	-	1,496	10,480	296	488	21,500	34,260
	200	6.41	10.77	2.69	-	-	1,608	10,180	408	678	21,500	34,374
	350	8.34	23.4	5.85	-	-	2,090	9,340	885	1,475	21,500	35,290
Conven-	50	12.42	6.96	-	10.68	0.89	3,740	25,400	271	418	51,100	80,929
tional	100	12.42	11.60	-	15.32	1.28	3,740	25,400	445	697	51,100	81,382
(Maximum)	146*	12.42	15.90	-	19.62	1.64	3,740	25,400	603	953	51,100	81,796
	200	13.38	22.5	-	26.5	2.21	4,030	24,400	853	1,348	51,100	81,731
	350	17.09	48.0	-	53.1	4.42	5,140	22,000	1,812	2,880	51,100	82,932
Vertical/	50	11.27	6.31	-	7.81	0.65	3,540	24,200	246	398	46,000	74,384
Modular	100	11.9[illegible]	11.20	-	12.79	1.07	3,760	23,300	429	705	46,000	74,194
(Maximum)	150	12.77	16.60	-	18.30	1.52	4,010	22,500	634	1,046	46,000	74,190
	200	13.72	23.1	-	24.9	2.08	4,310	21,800	875	1,452	46,000	74,437
	350	17.88	50.2	-	52.6	4.38	5,610	20,000	1,896	3,160	46,000	76,666

*Break in Payload/Radius Curve.

TABLE XCII (C)

DEPLOYMENT: $87^{o}F$/S.L., STOL/VTOL, BRIGADE BASE UNITS (C)

Type Deployment	Delivery System	Radius (N. Mi.)	Cycles	Total Flight Hours	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Fuel Cost	Total Spares Cost	Total Variable Operating Cost
Major	Conventional	50	164	105.0	132.7	11.08	39,520	5,410	6,230	51,160
		100	169	172.4	201.0	16.76	40,730	7,940	10,010	58,680
		150	175	245.0	275.0	22.90	42,180	10,680	14,530	67,390
		200	184	323.8	355.0	29.6	44,300	13,800	19,320	77,420
		300	211	531.7	568.0	47.3	50,900	21,700	31,700	104,300
		342(Max)	229	648.1	686.0	57.2	55,200	26,300	38,900	120,400
	Vertical/ Modular	50	170	108.8	137.7	11.45	42,700	5,610	6,800	55,110
		100	178	181.5	212.0	17.64	44,700	8,370	11,210	64,280
		150	188	263.2	295.0	24.60	47,200	11,470	16,360	75,030
		200	200	352.0	386.0	32.15	50,200	15,000	22,000	87,200
		250	218	466.5	504.0	42.0	54,700	19,400	29,200	103,300
		277(Max)	229	535.9	575.0	47.90	57,500	22,000	33,700	113,200
		300	can not carry complete unit							
Tactical	Conventional	25	162	72.9	100.3	8.37	48,800	4,210	4,210	57,220
		50	164	105.0	132.7	11.08	49,400	5,410	6,230	61,040
		75	166	137.8	166.0	13.83	49,700	6,640	8,130	64,470
		100	169	172.4	201.0	16.76	50,900	7,940	10,010	68,850
		150	175	245.0	275.0	22.90	52,700	10,680	14,530	77,910
	Vertical/ Modular	25	167	75.2	103.5	8.64	52,400	4,340	4,510	61,250
		50	170	108.8	137.7	11.45	53,400	5,610	6,800	65,810
		75	174	144.4	174.0	14.50	54,600	6,960	8,960	70,520
		100	178	181.6	212.0	17.64	55,900	8,370	11,210	75,480
		150	188	263.2	295.0	24.60	59,000	11,470	16,360	86,830

TABLE XCIII (C)

DEPLOYMENT: 83°F/2000FT, STOL/VTOL, BRIGADE BASE UNITS (C)

Type Deploy-ment	Delivery System	Radius (N. Mi.)	Cycles	Total Flight Hours	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Fuel Cost	Total Spares Cost	Total Variable Operating Cost
Major	Conven-tional	50	179	114.6	145.0	12.08	43,100	6,090	6,880	56,070
		100	189	192.8	225.0	18.75	45,500	8,850	11,600	65,950
		150	201	281.0	316.0	26.3	48,400	12,120	16,860	77,380
		200	216	380.0	417.0	34.7	52,100	15,880	22,800	90,780
		235(Max)	229	464.9	504.0	42.0	55,200	19,000	27,900	102,100
		300	can not carry complete unit							
	Vertical/ Modular	50	195	124.8	158.0	13.16	48,900	6,630	7,860	63,390
		100	213	217.0	254.0	21.2	53,500	9,970	13,670	77,140
		150	225	315.0	354.0	29.4	56,500	13,570	19,850	89,920
		172(Max)	229	357.0	396.0	33.0	57,500	15,100	22,500	95,100
		200	can not carry complete unit							
		300	can not carry complete unit							
Tactical	Conven-tional	25	175	78.8	108.5	9.02	52,700	4,830	4,730	62,260
		50	179	114.6	145.0	12.08	53,900	6,090	6,880	66,870
		75	184	152.7	184.0	15.53	55,400	7,490	9,160	72,050
		100	189	192.8	225.0	18.75	56,900	8,850	11,600	77,350
		150	201	281.0	316.0	26.3	60,500	12,120	16,860	89,480
		235(Max)	229	465.0	504.0	42.0	68,900	19,000	27,900	115,800
	Vertical/ Modular	25	189	85.1	117.0	9.77	59,300	5,220	5,360	69,880
		50	195	124.8	158.0	13.16	61,200	6,630	7,860	75,690
		75	201	166.8	201.0	16.74	63,100	8,180	10,500	81,780
		100	213	217.0	254.0	21.2	66,900	9,970	13,670	90,540
		150	225	315.0	354.0	29.4	70,700	13,570	19,850	104,120
		172(Max)	229	357.0	396.0	33.0	71,900	15,100	22,500	109,500

TABLE XCIV (C)

DEPLOYMENT: 87°F/S.L., STOL/VTOL, INFANTRY BATTALION (C)

Type Deploy-ment	Delivery Systems	Radius (N. Mi.)	Cycles	Total Flight Hours	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Fuel Cost	Total Spares Cost	Total Variable Operating Cost
Major	Conven-tional	50	37	23.7	30.0	2.50	60,300	1,236	1,420	62,956
		100	38	38.8	45.2	3.77	61,900	1,786	2,330	66,016
		150	39	54.6	61.2	5.10	63,600	2,390	3,280	69,270
		200	40	70.4	77.2	6.43	65,200	3,000	4,230	72,430
		300	45	113.4	121.0	10.08	73,400	4,620	6,800	84,820
		373(Max)	51	152.5	161.0	13.42	83,100	6,270	9,150	98,520
	Vertical/ Modular	50	39	25.0	31.6	2.63	66,300	1,303	1,575	69,178
		100	40	40.8	47.6	3.96	68,000	1,880	2,570	72,450
		150	42	58.8	65.9	5.49	71,400	2,570	3,700	77,670
		200	44	77.4	84.9	7.07	74,800	3,300	4,880	82,980
		300	50	126.0	134.5	11.20	85,000	5,130	7,940	98,070
		373(Max)	69	206.0	211.0	17.52	117,300	8,490	12,980	138,770
Tactical	Conven-tional	25	37	16.65	22.9	1.91	62,500	969	1,000	64,469
		50	37	23.7	30.0	2.50	62,500	1,236	1,420	65,156
		75	38	31.5	38.0	3.16	64,200	1,528	1,890	67,618
		100	38	38.8	45.2	3.77	64,200	1,786	2,330	68,316
		150	39	54.6	61.2	5.10	65,900	2,390	3,280	71,570
		373(Max)	51	152.5	161.0	13.42	86,200	6,270	9,150	101,620
	Vertical/ Modular	25	38	17.10	23.6	1.96	66,900	996	1,077	68,973
		50	39	25.00	31.6	2.63	68,700	1,303	1,575	71,578
		75	39	32.37	39.0	3.25	68,700	1,568	2,040	72,308
		100	40	40.80	47.6	3.96	70,400	1,880	2,570	74,850
		150	42	58.80	65.9	5.49	73,900	2,570	3,700	80,170
		373(Max)	69	206.31	211.0	17.52	121,400	8,490	12,980	142,870

TABLE XCV (C)

DEPLOYMENT: 83°F/2000 FT, STOL/VTOL, INFANTRY BATTALION (C)

Type Deploy-ment	Delivery Systems	Radius (N. Mi.)	Cycles	Total Flight Hours	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Fuel Cost	Total Spares Cost	Total Variable Operating Cost
Major	**Conven-tional**	50	41	26.2	33.2	2.76	66,800	1,394	1,572	69,766
		100	42	42.8	50.0	4.17	68,500	1,966	2,570	73,036
		150	44	61.6	69.0	5.76	71,700	2,650	3,700	78,050
		200	47	82.7	90.6	7.55	76,600	3,450	4,960	85,010
		300	54	136.1	145.2	12.10	88,000	5,360	8,170	101,530
		395(Max)	67	216.4	228.0	19.0	109,200	8,240	12,980	130,420
	Vertical/ Modular	50	43	27.5	34.8	2.90	73,100	1,462	1,733	76,295
		100	46	46.9	54.8	4.56	78,200	2,150	2,950	83,300
		150	48	67.2	75.3	6.28	81,600	2,890	4,230	88,720
		200	52	91.5	100.2	8.36	88,400	3,820	5,760	97,980
		300	64	161.3	172.2	14.36	108,800	6,350	10,160	125,310
		395(Max)	83	268.1	282.0	23.5	141,100	10,210	16,890	168,200
Tactical	Conven-tional	25	40	18.0	24.8	2.07	67,600	1,104	1,080	69,784
		50	41	26.2	33.2	2.76	69,300	1,394	1,572	72,266
		75	42	34.8	42.0	3.50	71,000	1,709	2,090	74,799
		100	42	42.8	50.0	4.17	71,000	1,966	2,570	75,536
		150	44	61.6	69.0	5.76	74,400	2,650	3,700	80,750
		395(Max)	67	216.4	228.0	19.0	113,200	8,240	12,980	134,420
	Vertical/ Modular	25	42	18.90	26.0	2.17	73,900	1,159	1,190	76,249
		50	43	27.5	34.8	2.90	75,700	1,462	1,733	78,895
		75	44	36.5	44.0	3.67	77,400	1,791	2,300	81,491
		100	46	46.9	54.8	4.56	81,000	2,150	2,950	86,100
		150	48	67.2	75.3	6.28	84,500	2,890	4,230	91,620
		395(Max)	83	268.1	282.0	23.5	146,100	10,210	16,890	173,200

TABLE XCVI (C)

DEPLOYMENT: 87°F/S.L., STOL/VTOL, ENGINEERING PLATOON (C)

Type Deploy-ment	Delivery System	Radius (N. Mi.)	Cycles	Total Flight Hours	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Fuel Cost	Total Spares Cost	Total Variable Operating Cost
Major	Conven-	50	25	16.00	21.0	1.75	40,800	835	960	42,595
	tional	100	25	25.50	30.5	2.54	40,800	1,175	1,530	43,505
		150	25	35.0	40.0	3.33	40,800	1,530	2,100	44,430
		200	26	45.80	51.0	4.25	42,400	1,950	2,750	47,100
		300	30	75.60	81.6	6.80	48,900	3.080	4,540	56,520
		340(Max)	34	95.90	102.8	8.55	55,400	3,890	5,750	65,040
	Vertical/	50	25	16.00	21.0	1.75	42,500	835	1,008	44,343
	Modular	100	26	26.50	31.7	2.64	44,200	1,222	1,669	47,091
		150	27	37.80	43.2	3.60	45,900	1,652	2,380	49,932
		200	28	49.30	54.3	4.57	47,600	2,100	3,110	52,810
		275(Max)	34	79.20	86.0	7.17	57,800	3,260	3,990	66,050
		300	can not carry complete unit							
	Conven-	25	25	11.25	16.25	13.53	42,300	655	675	43,630
	tional	50	25	16.00	21.0	1.75	42,300	835	960	44,095
		75	25	20.80	25.8	2.14	42,300	1,005	1,248	44,553
		100	25	25.50	30.5	2.54	42,300	1,175	1,530	45,005
		150	25	35.0	40.0	3.33	42,300	1,530	2,100	45,930
		340(Max)	34	95.90	102.8	8.55	57,500	3,890	5,750	67,140
	Vertical/	25	25	11.25	16.25	13.53	44,000	655	709	45,364
	Modular	50	25	16.00	21.0	1.75	44,000	835	1,008	45,843
		75	26	21.60	26.8	2.23	45,800	1,045	1,360	48,205
		100	26	26.50	31.7	2.64	45,800	1,222	1,669	48,691
		150	27	37.80	43.2	3.60	47,500	1,652	2,380	51,532
		275(Max)	34	79.20	8.60	7.17	59,800	3,260	4,990	68,050

TABLE XCVII (C)

DEPLOYMENT: 83°F/2000 FT, STOL/VTOL, ENGINEERING PLATOON (C)

Type Deploy-ment	Delivery System	Radius (N. Mi.)	Cycles	Total Flight Hours	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Fuel Cost	Total Spares Cost	Total Variable Operating Cost
Major	Conven-tional	50	26	16.64	21.8	1.82	42,400	884	998	44,282
		100	27	27.50	32.9	2.74	44,000	1,264	1,650	46,914
		150	28	39.20	44.8	3.73	45,600	1,688	2,350	49,638
		200	31	54.60	60.8	5.06	50,500	2,280	3,280	56,060
		232(Max)	34	68.00	74.8	6.23	55,400	2,740	4,080	62,220
		300	can not carry complete unit							
	Vertical/ Modular	50	27	17.28	22.7	1.89	45,900	918	1,089	47,907
		100	29	29.60	34.8	2.95	49,300	1,357	1,865	52,522
		150	33	46.20	52.8	4.40	56,100	1,990	2,910	61,000
		160(Max)	34	49.60	56.5	4.70	57,800	2,140	3,120	63,060
		200	can not carry complete unit							
		300	can not carry complete unit							
Tactical	Conven-tional	25	25	11.25	16.25	1.35	42,300	690	675	43,665
		50	26	16.64	21.8	1.82	43,900	884	998	45,782
		75	26	21.60	26.8	2.23	43,900	1,058	1,296	46,254
		100	27	27.50	32.9	2.74	45,600	1,264	1,650	48,514
		150	28	39.20	44.8	3.73	47,300	1,688	2,350	51,338
		232(Max)	34	68.00	74.8	6.23	57,500	2,740	4,080	64,320
	Vertical/ Modular	25	27	12.15	17.55	1.46	46,700	745	765	48,210
		50	27	17.28	22.7	1.89	46,700	918	1.089	48,707
		75	28	23.20	28.8	2.40	48,400	1,140	1,462	51,002
		100	29	29.60	34.8	2.95	50,200	1,357	1,865	53,422
		150	33	46.20	52.8	4.40	57,100	1,990	2,910	62,000
		160(Max)	34	49.60	56.5	4.70	58,800	2,140	3,120	64,060

TABLE XCVIII (C)

DEPLOYMENT: 87°F/S.L., STOL/VTOL, HOWITZER BATTERY (C)

Type Deploy-ment	Delivery System	Radius (N. Mi.)	Cycles	Total Flight Hours	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Fuel Cost	Total Spares Cost	Total Variable Operating Cost
Major	Conven-tional	50	8	5.12	6.48	0.54	13.040	267	307	13,614
		100	8	8.16	9.53	0.79	13,040	376	490	13,906
		150	8	11.20	12.57	1.05	13,040	490	672	14,202
		200	8	14.08	15.44	1.29	13,040	600	845	14,485
		300	8	20.20	21.50	1.79	13,040	821	1,212	15,073
		373(Max)	9	26.90	28.40	2.37	14,670	1,107	1,614	17,391
	Vertical/ Modular	50	8	5.12	6.48	0.54	13,600	267	323	14,190
		100	8	8.16	9.53	0.79	13,600	376	514	14,490
		150	8	11.20	12.57	1.05	13,600	490	706	14,796
		200	8	14.08	15.44	1.29	13,600	600	887	15,087
		300	9	22.70	24.20	2.02	15,300	923	1,430	17,653
		373(Max)	11	32.90	34.8	2.79	18,700	1,353	2,070	22,123
Tactical	Conven-tional	25	8	3.60	4.96	0.41	13,520	210	216	13,946
		50	8	5.12	6.48	0.58	13,520	267	307	14,094
		75	8	6.64	8.33	0.69	13,520	322	398	14,240
		100	8	8.16	9.53	0.79	13,520	376	490	14,386
		150	8	11.20	12.57	1.05	13,520	490	672	14,682
		373(Max)	9	26.90	28.40	2.37	15,210	1,107	1,614	17,931
	Vertical/ Modular	25	8	3.60	4.96	0.41	14,080	210	227	14,517
		50	8	5.12	6.48	0.58	14,080	267	323	14,670
		75	8	6.64	8.33	0.69	14,080	322	418	14,820
		100	8	8.16	9.53	0.79	14,080	376	514	14,970
		150	8	11.20	12.57	1.05	14,080	490	706	15,276
		373(Max)	11	32.90	34.8	2.79	19,360	1,353	2,070	22,783

TABLE XCIX (C)

DEPLOYMENT: $83^{o}F/2000$ FT, STOL/VTOL, HOWITZER BATTERY (C)

Type Deploy-ment	Delivery System	Radius (N. Mi.)	Cycles	Total Flight Hours	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Fuel Cost	Total Spares Cost	Total Variable Operating Cost
Major	Conven-tional	50	8	5.12	6.48	0.54	13,040	272	307	13,619
		100	8	8.16	9.53	0.79	13,040	374	490	13,904
		150	8	11.20	12.57	1.05	13,040	482	672	14,194
		200	8	14.08	15.44	1.29	13,040	588	845	14,473
		300	10	25.20	26.9	2.24	16,300	992	1,512	18,804
		395(Max)	12	38.80	40.8	3.40	19,560	1,476	2,330	23,366
	Vertical/ Modular	50	8	5.12	6.48	0.54	13,600	272	323	14,195
		100	8	8.16	9.53	0.79	13,600	374	514	14,488
		150	9	11.20	14.10	1.18	15,300	543	706	16,549
		200	10	17.60	19.30	1.61	17,000	735	1,109	18,862
		300	12	30.20	32.3	2.69	20,400	1,190	1,903	23,493
		395(Max)	14	45.20	47.6	3.97	23,900	1,722	2,850	28,372
Tactical	Conven-tional	25	8	3.60	4.96	0.41	13,520	221	216	13,957
		50	8	5.12	6.48	0.58	13,520	272	307	14,099
		75	8	6.64	8.33	0.69	13,520	326	398	14,244
		100	8	8.16	9.53	0.79	13,520	374	490	14,384
		150	8	11.20	12.57	1.05	13,520	482	672	14,674
		395(Max)	12	38.80	40.8	3.40	20,280	1,476	2,330	24,086
	Vertical/ Modular	25	8	3.60	4.96	0.41	14,080	221	227	14,528
		50	8	5.12	6.48	0.54	14,080	272	323	14,675
		75	8	6.64	8.33	0.69	14,080	326	418	14,824
		100	8	8.16	9.53	0.79	14,080	374	514	14,968
		150	9	11.20	14.10	1.18	15,840	543	706	17,089
		395(Max)	14	45.20	47.6	3.97	24,640	1,722	2,850	29,212

TABLE C (C)

DEPLOYMENT: 83°F/2000 FT, STOL/VTOL, HOWITZER BATTERY (C)

Temp/Alt	Delivery System	Radius (N. Mi.)	Cycles	Total Flight Hours	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Fuel Cost	Total Spares Cost	Total Variable Operating Cost
87°F/SL	Conventional	50	156	87.4	113.9	8.60	37,600	4,290	5,150	47,040
		100	156	145.9	172.4	14.35	37,600	6,400	8,740	52,740
		150	156	202.8	229.3	19.10	37,600	8,580	12,170	58,350
		200	156	262.1	288.6	24.02	37,600	10,760	15,600	63,960
		300	157	383.1	409.8	34.1	37,800	14,980	22,600	75,380
		392(Max)	164	510.0	537.9	44.8	39,500	20,000	30,700	90,200
	Vertical/Modular	50	156	87.4	113.9	8.60	39,200	4,290	5,400	48,890
		100	156	145.9	172.4	14.35	39,200	6,400	9,170	54,770
		150	156	202.8	229.3	19.10	39,200	8,580	12,780	60,560
		200	156	262.1	288.6	24.02	39,200	10,760	16,400	66,360
		300	158	385.5	412.4	34.4	39,700	14,980	23,700	78,380
		392(Max)	168	522.5	551.1	45.9	42,200	20,500	32,900	95,600
83°F/2000 FT	Conventional	50	156	87.4	113.9	8.60	37,600	4,210	5,150	46,960
		100	156	145.9	172.4	14.35	37,600	6,240	8,740	52,580
		150	156	202.8	229.3	19.10	37,600	8,420	12,170	58,190
		200	156	262.1	288.6	24.02	37,600	10,450	15,600	63,650
		300	157	383.1	409.8	34.10	37,800	14,760	22,800	75,350
		392(Max)	164	510.0	537.9	44.8	39,500	19,350	30,100	88,950
	Vertical/Modular	50	156	87.4	113.9	8.60	39,200	4,210	5,400	48,810
		100	156	145.9	172.4	14.35	39,200	6,240	9,170	54,610
		150	156	202.8	229.3	19.10	39,200	8,420	12,780	60,400
		200	156	262.1	288.6	24.02	39,200	10,450	16,380	66,030
		300	158	385.5	412.3	34.4	39,700	14,850	24,000	78,550
		392(Max)	168	522.5	551.1	45.9	42,200	19,820	32,900	94,920

TABLE CI (C)

MAJOR DEPLOYMENT: STOL/STOL, INFANTRY BATTALION (U)

Temp/Alt	Delivery System	Radius (N. Mi.)	Cycles	Total Flight Hours	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Fuel Cost	Total Spares Cost	Total Variable Operating Cost
$87^{o}F$/SL	Conven-tional	50	37	20.7	27.0	2.25	8,920	1,018	1,221	11,159
		100	37	34.6	40.9	3.41	8,920	1,517	2,070	12,507
		150	37	48.1	54.4	4.53	8,920	2,040	2,890	13,850
		200	37	62.2	68.5	6.71	8,920	2,550	3,700	15,170
		300	37	90.3	96.6	8.05	8,920	3,550	5,370	17,840
		392(Max)	38	118.2	124.7	10.30	9,160	4,640	7,110	20,910
	Vertical/ Modular	50	37	20.7	27.0	2.25	9,290	1,018	1,282	11,590
		100	37	34.6	40.9	3.41	9,290	1,517	2,180	12,987
		150	37	48.1	54.4	4.53	9,290	2,040	3,030	14,360
		200	37	62.2	68.5	6.71	9,290	2,550	3,890	15,730
		300	37	90.3	96.6	8.05	9,290	3,550	5,620	18,460
		392(Max)	38	118.2	124.7	10.30	9,540	4,640	7,450	21,630
$83^{o}F$/ 2000 FT	Conven-tional	50	37	20.7	27.0	2.25	8,920	999	1,221	11,140
		100	37	34.6	40.9	3.41	8,920	1,480	2,070	12,470
		150	37	48.1	54.4	4.53	8,920	1,998	2,890	13,808
		200	37	62.2	68.5	6.71	8,920	2,480	3,700	15,100
		300	37	90.3	96.6	8.05	8,920	3,480	5,370	17,770
		392(Max)	38	118.2	124.7	10.30	9,160	4,480	7,110	20,750
	Vertical/ Modular	50	37	20.7	27.0	2.25	9,290	999	1,282	11,571
		100	37	34.6	40.9	3.41	9,290	1,480	2,190	12,950
		150	37	48.1	54.4	4.53	9,290	1,998	3,030	14,318
		200	37	62.2	68.5	6.71	9,290	2,480	3,890	15,660
		300	37	90.3	96.6	8.05	9,290	3,480	5,620	18,390
		392(Max)	38	118.2	124.7	10.30	9,540	4,480	7,450	21,470

TABLE CII (C)

MAJOR DEPLOYMENT: STOL/STOL, ENGINEERING PLATOON (U)

Temp/Alt	Delivery System	Radius (N. Mi.)	Cycles	Total Flight Hours	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Fuel Cost	Total Spares Cost	Total Variable Operating Cost
87°F/SL	Conven-tional	50	24	13.4	18.2	1.52	5,780	660	792	7,232
		100	24	22.4	27.2	2.27	5,780	984	1,344	8,108
		150	24	31.2	36.0	3.00	5,780	1,320	1,872	8,972
		200	24	40.3	45.1	3.76	5,780	1,656	2,400	9,836
		300	24	58.6	63.4	5.28	5,780	2,300	3,480	11,560
		392(Max)	25	77.8	82.8	6.90	6,030	3,050	4,680	13,760
	Vertical/ Modular	50	24	13.4	18.2	1.52	6,020	660	832	7,512
		100	24	22.4	28.2	2.27	6,020	984	1,411	8,415
		150	24	31.2	36.0	3.00	6,020	1,320	1,966	9,306
		200	24	40.3	45.1	3.76	6,020	1,656	2,520	10,196
		300	24	58.6	63.4	5.28	6,020	2,300	3,650	11,970
		392(Max)	25	77.8	82.8	6.90	6,280	3,050	4,900	14,230
83°F/ 2000 Ft	Conven-tional	50	24	13.4	18.2	1.52	5,780	648	792	7,220
		100	24	22.4	27.2	2.27	5,780	960	1,344	8,084
		150	24	31.2	36.0	3.00	5,780	1,296	1,872	8,948
		200	24	40.3	45.1	3.76	5,780	1,608	2,400	9,788
		300	24	58.6	63.4	5.28	5,780	2,260	3,480	11,520
		392(Max)	25	77.8	82.8	6.90	6,030	2,950	4,680	13,660
	Vertical/ Modular	50	24	13.4	18.2	1.52	6,020	648	832	7,500
		100	24	22.4	27.2	2.27	6,020	960	1,411	8,391
		150	24	31.2	36.0	3.00	6,020	1,296	1,966	9,282
		200	24	40.3	45.1	3.76	6,020	1,608	2,520	10,148
		300	24	58.6	63.4	5.28	6,020	2,260	3,650	11,930
		392(Max)	25	77.8	82.8	6.90	6,280	2,950	4,900	14,130

TABLE CIII (C)

MAJOR DEPLOYMENT: STOL/STOL, HOWITZER BATTERY (U)

Temp/Alt	Delivery System	Radius (N. Mi.)	Cycles	Total Flight Hours	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Fuel Cost	Total Spares Cost	Total Variable Operating Cost
87°F/SL	Conventional	50	8	4.5	6.8	0.58	1,928	220	264	2,412
		100	8	7.5	8.8	0.73	1,928	328	448	2,704
		150	8	10.4	11.7	0.98	1,928	440	624	2,992
		200	8	13.4	14.7	1.23	1,928	552	800	3,280
		300	8	19.5	20.8	1.73	1,928	768	1,160	3,856
		392(Max)	8	24.9	26.2	2.18	1,928	976	1,496	4,400
	Vertical/Modular	50	8	4.5	6.8	0.58	2,010	220	277	2,507
		100	8	7.5	8.8	0.73	2,010	328	470	2,808
		150	8	10.4	11.7	0.98	2,010	440	655	3,105
		200	8	13.4	14.7	1.23	2,010	552	840	3,402
		300	8	19.5	20.8	1.73	2,010	768	1,216	3,994
		392(Max)	8	24.9	26.2	2.18	2,010	976	1,568	4,554
83°F/2000 FT	Conventional	50	8	4.5	6.8	0.58	1,928	216	264	2,408
		100	8	7.5	8.8	0.73	1,928	320	448	2,696
		150	8	10.4	11.7	0.98	1,928	432	624	2,984
		200	8	13.4	14.7	1.23	1,928	536	800	3,264
		300	8	19.5	20.8	1.73	1,928	752	1,160	3,840
		392(Max)	8	24.9	26.2	2.18	1,928	944	1,496	4,368
	Vertical/Modular	50	8	4.5	6.8	0.58	2,010	216	277	2,503
		100	8	7.5	8.8	0.78	2,010	320	470	2,800
		150	8	10.4	11.7	0.98	2,010	432	655	3,097
		200	8	13.4	14.7	1.23	2,010	536	840	3,386
		300	8	19.5	20.8	1.73	2,010	752	1,216	3,978
		392(Max)	8	24.9	26.2	2.18	2,010	944	1,568	4,522

TABLE CIV (C)

TACTICAL REDEPLOYMENT: VTOL/VTOL, BRIGADE BASE UNITS (U)

Temp/Alt	Delivery System	Radius (N. Mi.)	Cycles	Total Flight Hours	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Fuel Cost	Total Spares Cost	Total Variable Operating Cost
87°F/SL	Conventional	25	171	87.2	116.2	9.70	51,500	5,680	5,230	62,410
		50	178	124.5	154.9	12.90	53,600	7,140	7,470	68,210
		75	187	166.3	198.3	16.53	56,300	8,750	9,980	75,030
		100	198	212.0	245.5	20.4	59,600	10,630	12,720	82,950
		148(Max)	229	327.5	366.0	30.5	69,000	15,340	19,640	103,980
		150	can not carry complete unit							
	Vertical/ Modular	25	183	93.4	124.5	10.39	57,450	6,080	5,880	69,410
		50	192	134.3	167.0	13.92	60,250	7,700	8,470	76,420
		75	205	182.3	217.6	17.30	64,400	9,590	11,500	85,490
		100	220	257.5	271.6	21.4	69,000	11,810	16,220	97,030
		112(Max)	229	266.0	304.8	25.4	71,900	13,170	16,760	101,830
		150	can not carry complete unit							
83°F/ 2000 FT	Conventional	25	196	99.9	133.3	11.10	59,000	6,430	5,990	71,420
		50	209	146.3	181.8	15.14	62,900	8,190	8,780	79,870
		75	225	200.2	238.5	19.88	67,700	10,400	12,010	90,110
		82(Max)	229	215.3	254.2	21.2	68,900	11,340	12,920	93,160
		100	can not carry complete unit							
		150	can not carry complete unit							
	Vertical/ Modular	25	220	112.2	149.6	12.45	69,100	7,220	7,070	83,390
		37 (Max)	229	137.4	176.3	14.68	71,900	8,590	8,660	89,150
		50	can not carry complete unit							
		75	can not carry complete unit							
		100	can not carry complete unit							
		150	can not carry complete unit							

TABLE CV (C)

TACTICAL REDEPLOYMENT: VTOL/VTOL, INFANTRY BATTALION (U)

Temp/Alt	Delivery System	Radius (N. Mi.)	Cycles	Total Flight Hours	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Fuel Lost	Total Spares Cost	Total Variable Operating Cost
87°F/SL	Conven-tional	25	38	19.38	25.85	2.15	64,200	1,262	1,163	66,625
		50	39	27.3	33,90	2,83	65,900	1,564	1,638	69,102
		75	41	36.5	43.5	3.62	69,300	1,920	2,190	73,410
		100	43	46.0	53.3	4.45	72,500	2,310	2,760	77,570
		150	49	70.6	78.8	6.57	82,800	3,300	4,240	90,340
		285(Max)	87	214.0	229.0	19.1	147,000	9,140	12,840	168,980
	Vertical/ Modular	25	40	20.4	27.2	2.27	70,400	1,328	1,285	73,013
		50	42	29.4	36.6	3.04	73,900	1,684	1,852	77,436
		75	44	39.2	46.6	3.89	77,400	2,060	2,470	81,930
		100	47	50.3	58.3	4.85	82,700	2,520	3,170	88,390
		150	56	80.6	90.2	7.51	98,600	3,770	5,080	107,450
		250(Max)	87	190.5	206.0	17.15	153,000	8,280	12,000	173,280
83°F/ 2000 FT	Conven-tional	25	42	21.4	28.6	2.38	71,000	1,380	1,282	73,662
		50	45	31.5	39.1	3.26	76,100	1,760	1,890	79,750
		75	48	42.7	50.8	4.24	81,100	2,220	2,560	85,880
		100	51	54.6	63.2	5.26	86,200	2,680	3,280	92,160
		150	62	89.3	99.8	8.32	104,500	4,070	5,350	113,920
		230(Max)	87	177.5	192.0	16.0	147,000	7,530	10,640	165,170
	Vertical/ Modular	25	47	23.9	32.0	2.66	82,700	1,540	1,508	85,748
		50	50	35.0	43.5	3.63	88,000	1,960	2,202	92,162
		75	55	48.9	58.3	4.86	96,800	2,540	3,080	102,420
		100	60	64.2	74.4	6.20	105,600	3,160	4,050	112,810
		150	76	109.4	103.3	8.60	133,800	4,990	6,880	145,670
		185(Max)	87	148.8	163.7	13.62	153,000	6,490	9,350	168,840

TABLE CVI (C)

TACTICAL REDEPLOYMENT: VTOL/VTOL, ENGINEERING PLATOON (U)

Temp/Alt	Delivery System	Radius (N. Mi.)	Cycles	Total Flight Hours	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Fuel Cost		Total Variable Operating Cost
87°F/SL	Conven-tional	25	25	12.75	17.75	1.48	42,300	830	765	43,895
		50	26	18.2	23.40	1.95	43,900	1,042	1,092	46,034
		75	27	24.0	29.4	2.45	45,600	1,263	1,440	48,303
		100	28	29.9	35.6	2.96	47,300	1,504	1,794	50,598
		150(Max)	34	49.0	55.8	4.65	57,500	2,290	2,940	62,730
	Vertical/ Modular	25	26	13.25	18.45	1.54	45,700	863	835	47,398
		50	28	19.6	25.2	2.10	49,300	1,123	1,235	51,658
		75	29	25.8	31.6	2.64	51,000	1,357	1,625	53,982
		100	32	34.2	40.7	3.39	56,300	1,720	2,150	60,170
		110(Max)	34	38.8	45.5	3.79	59,800	1,920	2,440	64,160
		150	can not carry complete unit							
83°F/ 2000 FT	Conven-tional	25	28	14.28	19.90	1.65	47,300	920	857	49,077
		50	30	21.0	27.0	2.25	50,700	1,180	1,260	53,140
		75	33	29.4	36.0	3.00	55,800	1,520	1,760	59,080
		82(Max)	34	32.0	38.8	3.23	57,500	1,680	2,020	61,200
		100	can not carry complete unit							
		150	can not carry complete unit							
	Vertical/ Modular	25	32	16.32	22.7	1.89	56,300	1,050	1,030	58,380
		40(Max)	34	21.1	27.9	23.2	59,800	1,290	1,330	62,420
		50	can not carry complete unit							
		75	can not carry complete unit							
		100	can not carry complete unit							
		150	can not carry complete unit							

TABLE CVII (C)

TACTICAL REDEPLCYMENT: VTOL/VTOL, HOWITZER BATTERY (U)

Temp/Alt	Delivery System	Radius (N. Mi.)	Cycles	Total Flight Hours	Total Cycle Hours	Number Aircraft (Oper. Day)	Total Cost Aircraft Lost	Total Fuel Cost	Total Spares Cost	Total Variable Operating Cost
87^oF/SL	Conven-tional	25	8	4. 08	5. 45	0. 45	13, 520	266	244	14, 030
		50	8	5. 6	6. 96	0. 58	13, 520	321	336	14, 177
		75	8	7. 1	8. 48	0. 71	13, 520	374	426	14, 320
		100	8	8. 6	9. 90	0. 83	13, 520	430	516	14, 466
		150	9	13. 0	14. 50	1. 21	15, 210	607	780	16, 597
		282(Max)	15	36. 6	39. 2	3. 26	25, 350	1, 575	2, 200	29, 125
	Vertical/ Modular	25	8	4. 08	5. 45	0. 45	14, 080	266	257	14, 603
		50	8	5. 6	6. 96	0. 58	14, 080	321	353	14, 754
		75	8	7. 1	8. 48	0. 71	14, 080	374	447	14, 901
		100	8	8. 6	9. 90	0. 83	14, 080	430	542	15, 052
		150	11	15. 8	17. 7	1. 48	19, 360	741	995	21, 096
		250(Max)	15	32. 9	35. 4	2. 95	26, 400	1, 428	2, 070	29, 898
83^oF/ 2000 Ft	Conven-tional	25	8	4. 08	5. 45	0. 45	13, 520	262	244	14, 026
		50	8	5. 6	6. 96	0. 58	13, 520	314	321	14, 155
		75	8	7. 1	8. 48	0. 71	13, 520	370	374	14, 264
		100	10	10. 7	12. 40	1. 03	16, 900	526	642	18, 068
		150	12	17. 3	19. 30	1. 61	20, 300	788	1, 040	22, 128
		230(Max)	15	30. 6	33. 2	2. 76	25, 350	1, 300	1, 840	28, 490
	Vertical/ Modular	25	8	4. 08	5. 45	0. 45	14, 080	262	266	14, 608
		50	9	6. 3	7. 83	0. 65	15, 840	353	397	16, 590
		75	10	8. 9	10. 60	0. 88	17, 600	462	561	18, 623
		100	11	11. 8	13. 64	1. 14	19, 360	579	743	20, 682
		150	14	20. 2	22. 60	1. 88	24, 700	920	1, 273	26, 893
		185(Max)	15	25. 7	28. 20	2. 35	26, 400	1, 120	1, 620	28, 140

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13. ABSTRACT

A concept for aerial delivery of supplies by dropping modules vertically through bottom doors in an aircraft was investigated. Preliminary analysis was conducted to determine the effect on the aircraft structural weight, strength, and aerodynamic performance. A preliminary design of the mechanical cargo handling system was completed. The dynamic effect of dropping cargo on the stability and control characteristics of the aircraft was investigated.

The system was evaluated in comparison to a conventional aerial delivery system for typical missions performed by a forward-area transport. The concept was shown to be advantageous for performing resupply missions when operating in the vertical flight mode. It is concluded that the concept has potential application to V/STOL or rotary-wing aircraft.

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